EXHIBIT A

United States Patent [19]

Lau

[11] **Patent Number: 4,835,763**

[45] **Date of Patent: May 30, 1989**

[54] **SURVIVABLE RING NETWORK**

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[73] Assignee: **Bell Communications Research, Inc.,** Livingston, N.J.

[21] Appl. No.: **152,238**

[22] Filed: **Feb. 4, 1988**

[51] **Int. Cl.⁴** **H04J 1/16;** H04J 3/14

[52] **U.S. Cl.** **370/16;** 370/88

[58] **Field of Search** 370/13, 16, 88, 84, 370/89, 95; 371/8, 11

[56] **References Cited**

U.S. PATENT DOCUMENTS

Re. 28,958	9/1976	Zafiropulo et al.	340/147 SC
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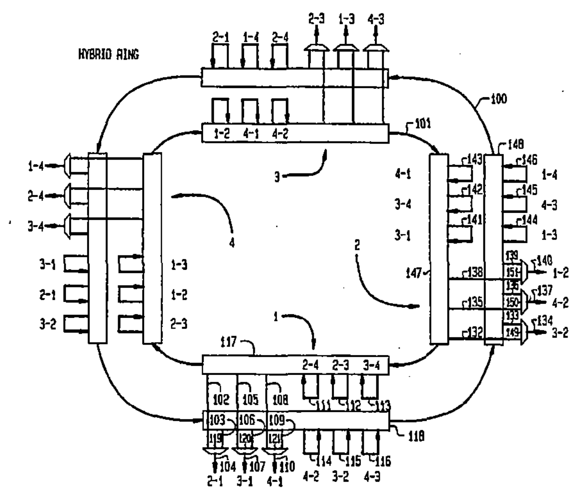
4,710,915	12/1987	Kitahara	370/16

Primary Examiner—Benedict V. Safourek
Assistant Examiner—Wellington Chin
Attorney, Agent, or Firm—James W. Falk; John T. Peoples

[57] **ABSTRACT**

A survivable ring network is disclosed that can withstand a cut link or failed node, without the need for a central controller or protection switching among links. The disclosed invention comprises two rings carrying identical multiplexed node-to-node communications in opposite directions. When a system error is detected in a downstream node, error signals are inserted in all subrate channels. Each subrate channel receiver receives identical communications from each ring. If one subrate channel has an error signal, the receiver selects the alternate channel.

8 Claims, 4 Drawing Sheets



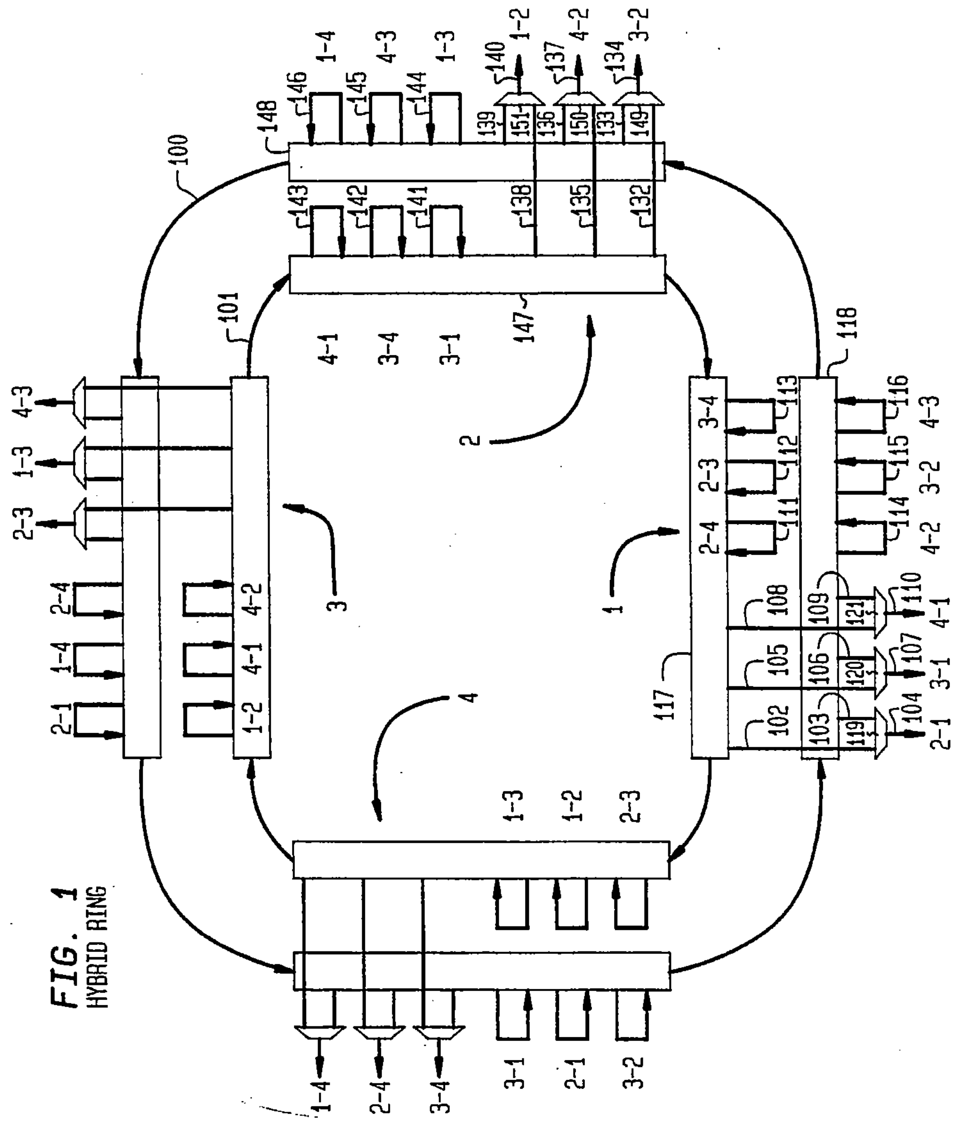


FIG. 1
HYBRID RING

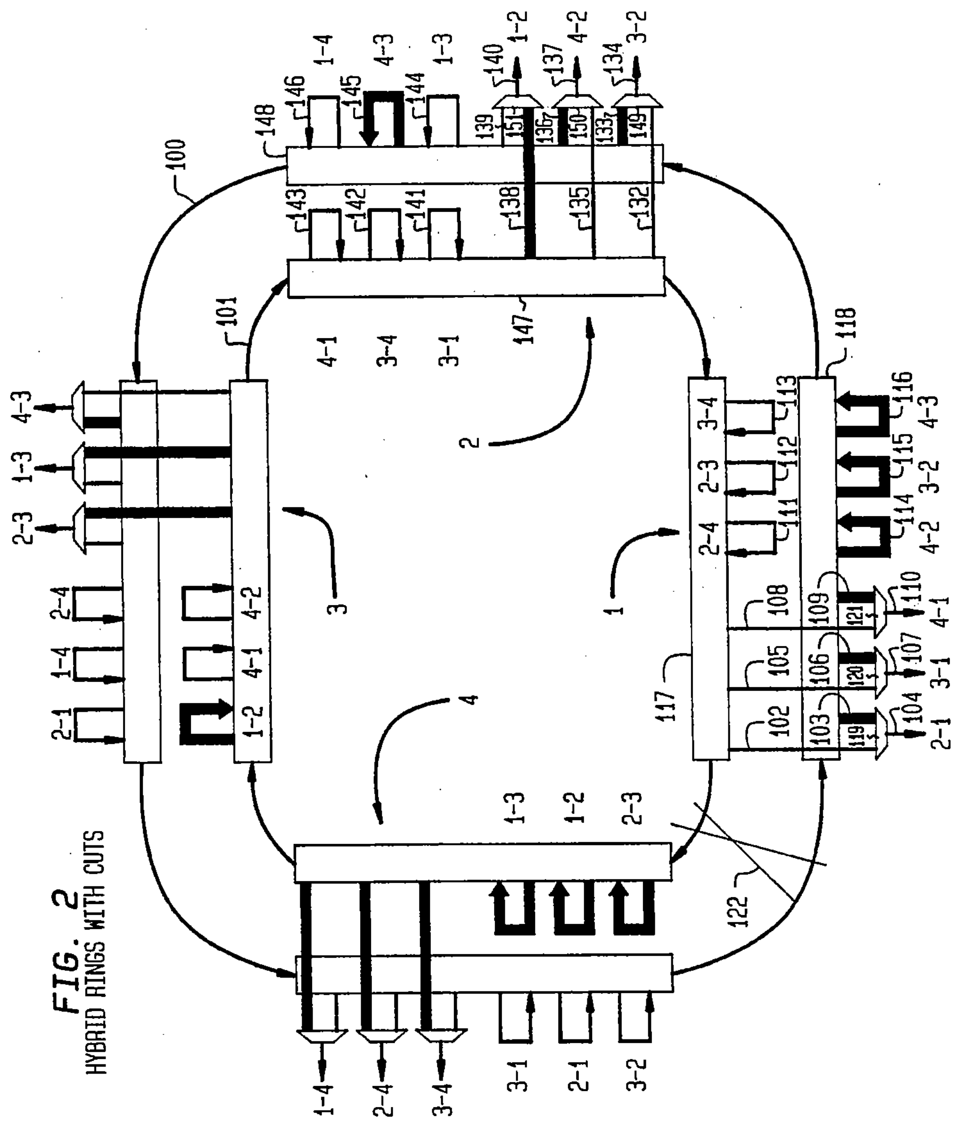


FIG. 2
HYBRID RINGS WITH CUTS

FIG. 3

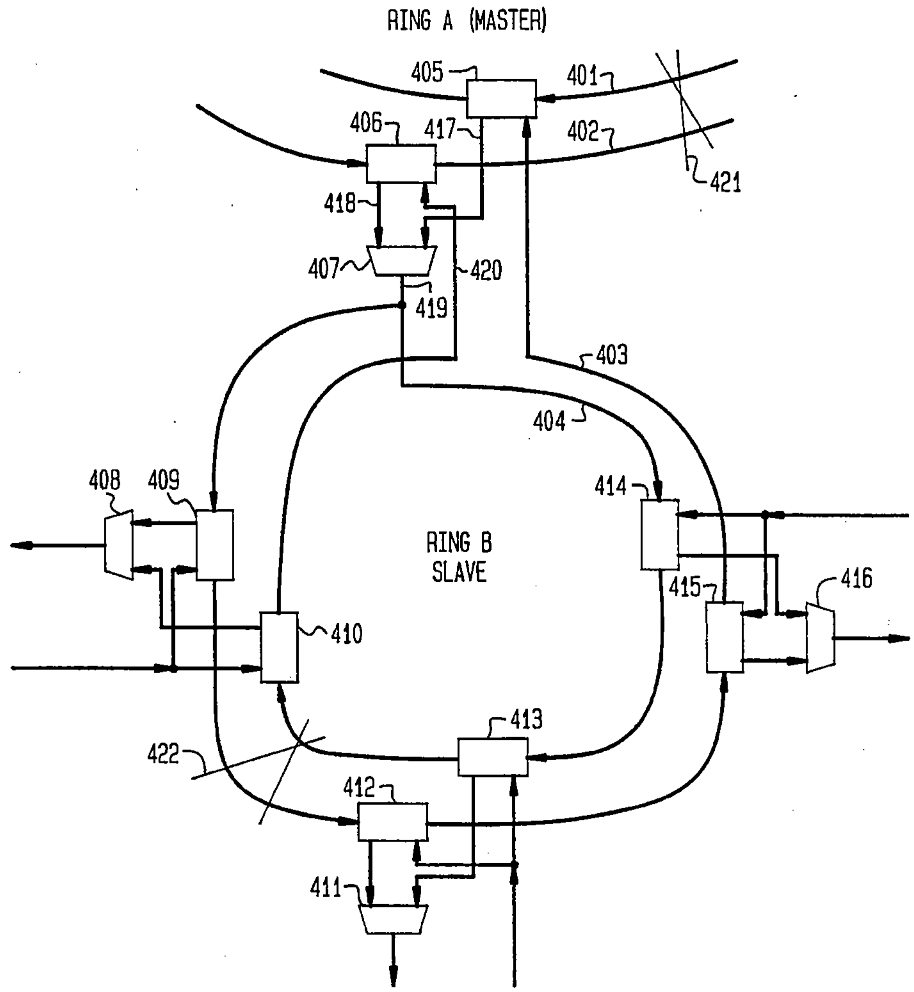
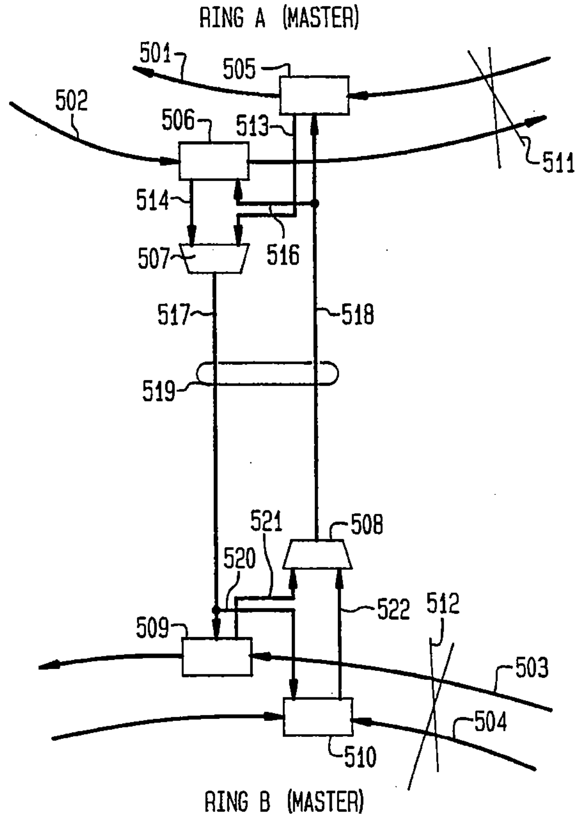

RING A (MASTER)
405
401
406
417
402
421
418
407
420
419
403
404
408
409
414
RING B
SLAVE
415
416
410
413
422
412
411

FIG. 4


RING A (MASTER)
501
505
502
506
513
511
514
516
507
517
518
519
521
508
520
522
512
509
503
504
510
RING B (MASTER)

SURVIVABLE RING NETWORK

FIELD OF THE INVENTION

The invention relates generally to a communications network. Specifically, it relates to a self-healing ring network.

BACKGROUND OF THE INVENTION

A ring communications network is made up of nodes that are connected in tandem by a unidirectional communications path. Each node receives transmissions from the adjacent upstream node, and if the communication is destined for a downstream node, the communication is re-transmitted to the adjacent downstream node. Otherwise, each node transmits its own communications to the adjacent downstream node.

A drawback of such a network is that a break in the ring would prevent any node upstream of the break from communicating with any node downstream of the break. Similarly, the complete failure of a node would have the same effect as a break in the ring.

Many designs have been proposed to minimize these difficulties. The most common approach is to provide a second communications ring parallel to the first. In that case, a fault in one ring could be bypassed by transferring communications to the second ring. Alternatively, if the second ring transmitted in the opposite direction as the first, a break in both rings between two adjacent nodes could be remedied by the nodes on either side of the break looping back communications received on one ring onto the other ring. Such a system is described in McNeilly et al, U.S. Pat. No. 3,652,798.

The main problem with such approaches is that the equipment required to detect and locate a fault, and then appropriately reconnect transmitters and receivers with the alternate ring, is complicated and costly.

SUMMARY OF THE INVENTION

These and other difficulties are alleviated by my invention. A subrate multiplexed signal is utilized for ring communications. Each node has the capability of demultiplexing the main signal into its constituent subrates (channels), and channels destined for that node (local channels) are sent to receiving equipment within the node, while channels destined for downstream nodes (through channels) are multiplexed with originating local channels, and the resultant high level signal is transmitted to the adjacent downstream node. This process is simultaneously performed using identical equipment in the node for a second ring transmitting in the opposite direction. If a node detects a fault in an incoming line, an error signal is placed on all of the channels following the demultiplexing. The receiving equipment in each node includes a selector which monitors the communications arriving on each local channel from both rings. If an error signal is detected on a local channel, the selector selects the communication from the associated channel of the other ring to send to the receiver.

In this way, a break in both rings between two adjacent nodes will not cause a failure in the system, and no complicated fault locating and switching equipment is required to continue service. Similarly, the complete failure of a node will not destroy communications among the remaining nodes.

It should be noted that unlike prior survivable ring arrangements which maintain their ring characteristics following a fault, my invention ceases functioning as a ring if the ring is broken. However, as previously discussed, communications among the nodes is maintained following such a break. I therefore term my network a hybrid ring, since it normally operates as a ring, but does not operate as a ring following a break in the ring or the loss of a node.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagram of the hybrid ring network;

FIG. 2 is a diagram of the hybrid ring network with a break in both rings;

FIG. 3 is a diagram of a portion of a master/slave arrangement of two hybrid ring networks; and

FIG. 4 is a diagram of a portion of a master/master arrangement of two hybrid ring networks.

DETAILED DESCRIPTION

An illustrative embodiment of my invention is depicted in FIG. 1. In discussing FIG. 1, it is helpful to have the background provided by the reference entitled "Draft of American National Standard for Telecommunications Digital Hierarchy Optical Interface Rates and Formats Specifications" dated Dec. 11, 1987 as transmitted to the Secretariat of the Excharge Carriers Standards Association, T_1 Committee-Telecommunications. This reference is incorporated herein by reference. My invention is an improvement to the basic communication methodology discussed in this reference. Node **1** comprises controllers **117** and **118** and selectors **119**–**121**. Controller **117** is connected with ring **101**, which carries signals in a clockwise direction, and controller **118** is connected with ring **100**, which carries signals in a counterclockwise direction. Illustratively, the signals on each ring comprise six subrate channels, each of which is dedicated to communications between a pre-selected pair of basically identical nodes. Each node feeds three subrate receivers (not shown), which in the case of node **1** have lines **104**, **107** and **110**, respectively, as input.

The channel carrying communications between nodes **1** and **2** would be extracted from ring **101** by controller **117** (by demultiplexing the signal on ring **101**), and sent to selector **119** over line **102**. Controller **118** would extract the associated channel off ring **100** and send it to selector **119** over line **103**. Selector **119** would select one of the signals arriving on lines **102** and **103**, based on the presence or absence of an error signal on either line. The selected signal would be sent to the receiver over line **104**. A transmitter (not shown) would transmit two identical signals destined for node **2**, one to controller **117** and one to controller **118**, for reinsertion into the respective loops.

Channels associated with communications between nodes **3** and **1**, and between nodes **4** and **1**, would operate in a similar manner utilizing selectors **120** and **121**, respectively. Controllers **117** and **118** then multiplex the three channels originating from node **1** with the three through channels, and transmit the resultant higher level signals on their associated loops (loop **101** toward node **4** and loop **100** toward node **2**). In this way, each node has two redundant communications paths to each of the other nodes, both paths being continuously active.

The simplicity and elegance of my invention becomes apparent when a break occurs in the rings, as shown in FIG. 2. If rings **100** and **101** are broken between node **1**

and node **4**, two simultaneous activities take place which will preserve communications paths among all of the nodes.

Each node continuously monitors and evaluates the integrity of the multiplexed subrate signals arriving at the node. Illustratively, this could be accomplished by detecting the absence of a carrier signal in an analog signal environment, or the lack of any incoming signal in a digital environment. When node **1** recognizes major line fault **122** in ring **100**, controller **118** inserts an error signal onto the six subrate channels. This could illustratively be accomplished by inserting a string of 1's on each channel in a digital environment. Node **4** performs the identical activity by similarly placing an error signal on the six subrate channels of ring **101**. After these two relatively simple procedures take place, the ring network otherwise operates normally.

In node **1**, selector **119** chooses line **102** because line **103** has an error signal on it (designated by dashed line **103**). Similarly, selector **120** selects line **105** because line **106** has an error signal, and selector **121** selects line **108** because line **109** contains an error signal. The three through channels on ring **100** that contain error signals are then multiplexed with the three local channels that now have valid data originating from node **1** and the higher level signal is transmitted to node **2** over ring **100**.

Because the higher level signal arriving at node **2** on ring **100** appears normal, controller **148** demultiplexes the higher level signal into its six subrate channels, three of which terminate at node **2**. The first local channel contains communications from node **3** to node **2**. An error signal was generated on this channel at node **1**. Controller **148** sends this error signal to selector **149** via line **133**. Selector **149** therefore selects line **132** from controller **147**, containing traffic from node **3** to node **2** over ring **101**, which is not affected by break **122**.

Similarly, selector **150** recognizes the error signal on line **136** and selects line **135**. Selector **151** receives communications from node **1** over line **139** from ring **100** and receives an error signal over line **138** from ring **101**. Therefor, selector **151** would select line **139**.

Communications from node **1** to node **3** and from node **1** to node **4** are multiplexed from lines **144** and **146** by controller **148**. Communications from node **4** to node **3** are also multiplexed from line **145** by controller **148**, thereby passing along the error signal contained therein to node **3** over ring **100**.

Each node operates in the above manner to insure continuity of communications among the nodes following a ring failure; or, as in the case of break **122**, a multiple ring failure between two adjacent nodes. If a node fails, the same process will maintain communications among the remaining nodes.

It should be readily apparent that other techniques could be employed without departing from the scope of my invention, such as designating the destination node within each message, and having each node read the destination of each message passing through the node, and selecting messages destined for itself.

FIG. **3** depicts an embodiment of my invention wherein two ring sets are joined in a dual-ring configuration at a common node (gateway node). Ring arrangement A is designated the master ring and ring arrangement B is designated the slave ring. Controller **405** of the gateway node extracts a pre-selected subrate channel off ring **401** and sends the extracted channel to selector **407** over line **417**. Controller **406** sends a similarly pre-selected subrate channel from ring **402** to selector **407** over line **418**. Selector **407** chooses a non-error signal line for insertion onto slave rings **403** and **404** via line **419**. In this way, any one break in the master rings **401** and **402** will not prevent a valid subrate channel from being inserted onto slave ring **403**.

Controllers **409** and **410** insert and extract communications on rings **403** and **404**, respectively, and selector **408** chooses a non-error signaled input. If, illustratively, break **422** occurs on rings **403** and **404**, controllers **412** and **410** will insert error signals on associated subrate paths, and controllers **409, 413, 414** and **415** would operate as if no break occurred. Selectors **408, 411** and **416** would select inputs that do not contain error signals. It should be readily apparent that a two-ring break in either the master ring or the slave ring would not result in the loss of communications between any two nodes. However, simultaneous breaks in both the master and slave rings would result in selected communications losses.

FIG. **4** depicts two interrelated rings that can withstand simultaneous breaks in both rings without loss of communications between any two nodes, by employing a master-master relationship. Instead of one gateway node connecting the two rings, one node on each master ring is connected by link **519**. Controllers **505** and **506** send a subrate communications channel to selector **507**, and controllers **509** and **510** send a subrate communications channel to selector **508**. If there is a break in ring A, selector **507** will select the non-error signal communication from line **513** or line **514** and transmit to ring B via line **517**, and similarly, if there is a break in ring B, selector **508** will select the non-error signal communication from line **521** or **522** and transmit to ring A via line **518**. It should be readily apparent that simultaneous breaks in both ring A and ring B will not result in the loss of communications between any two nodes.

My invention will work regardless of whether the ring networks are copper or fiber, and regardless of what higher rates and subrates are utilized. The dual ring embodiment depicted on FIG. **3** is most beneficially suited to multiple levels of subrating. For instance, in FIG. **3**, if ring A carried a signal which could be demultiplexed into two subchannels by controllers **405** and **406**, one subchannel could be sent to ring B by selector **407**. Controllers **409–410** and **412–415** on ring B would then further demultiplex the subchannel for communications terminating at nodes on ring B.

Those ordinarily skilled in the art could make obvious modifications to my invention without departing from its scope.

What is claimed is:

1. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a scond ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated subrate receivers, an improved node comprising

monitoring means, associated with the first ring and the second ring, for evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring, respectively, and

insertion means, associated with the demultiplexers and said monitoring means, for inserting an error

signal on designated ones of the subrate communications in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on the first ring or the second ring or both the first ring and the second ring.

2. In the communications network of claim 1, the improved node further comprising selector means associated with the demultiplexers for selecting, in response to the detection of said error signal on one of the subrate communications, another of the subrate communications that does not contain said error signal.

3. In the communications network of claim 1, the improved node wherein the multiplexers multiplex selected subrate communications containing said error signal into a multiplexed subrate communication for transmission onto the first ring or the second ring or both in correspondence to said detection of said error signal.

4. A communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each of said nodes including subrate transmitters and subrate receivers and further comprising:

monitoring means, associated with the first ring and the second ring, for evaluating the integrity of the multiplexed subrate communications on the associated first ring and the associated second ring, respectively,

means for demultiplexing the multiplexed subrate communications on the associated first ring and the associated second ring into subchannels wherein at least one of said subchannels is sent to one of the corresponding receivers,

insertion means associated with said demultiplexing means to insert an error signal on each of said subchannels in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on the associated first ring or the associated second ring or both the associated first ring and the associated second ring,

selector means associated with said demultiplexing means for selecting, in response to the detection of said error signal on one of the subchannels, one of the other subchannels, and

multiplexing means for multiplexing subchannels and inserting multiplexed subrate communications onto the associated first ring and the associated seocnd ring, respectively.

5. A communications network having a first grouping of nodes interconnected by a first ring arrangement, a second grouping of nodes interconnected by a second ring arrangement, each ring arrangement conveying multiplexed subrate communications in a first direction from node to node and conveying multiplexed subrate communications in a second direction from node to node, and each node includes subrate transmitters with associated multiplexers and demultiplexers with associated receivers, and wherein

each node comprises

monitoring means, associated with the ring arrangement connected to said each node, for evaluating the integrity of the multiplexed subrate communications on said associated ring arrangement,

insertion means, associated with its demultiplexers and its monitoring means, for inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed subrate communications on its said associated ring arrangement, and

selector means, associated with its demultiplexers, for selecting, in response to the detection of said error signal on a subrate communication, a subrate communication that does not contain an error signal, and

wherein a preselected node of the first ring arrangement comprises;

means, connected to the first ring arrangement and the second ring arrangement, for directing at least one subrate communication to the second ring arrangement and corresponding subrate communications from the second ring arrangement for multiplexing onto multiplexed subrate communications on the first ring arrangement.

6. The network of claim 5

wherein said subrate communication directed to the second ring arrangement is received by a preselected node of the second ring arrangement for multiplexing into multiplexed subrate communications around the second ring arrangement,

and wherein the subrate communications directed to the first ring arrangement originates at said preselected node of the second ring arrangement.

7. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated receivers, an improved method associated with each node comprising the steps of

evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring with monitoring means associated with both the first ring and the second ring, and

inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed communications on the first ring or the second ring or both the first ring and the second ring.

8. The method as recited in claim 7 further comprising the step of selecting, in response to the detection of said error signal on said at least one of the subrate communications, another of the subrate communications that does not contain an error.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,835,763

DATED : May 30, 1989

INVENTOR(S) : Chi-Leung Lau

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4, line 57, change "scond" to --second--.

Column 5, line 52, change "seocnd" to --second--.

Signed and Sealed this

Eighth Day of September, 1992

Attest:

DOUGLAS B. COMER

Attesting Officer

Acting Commissioner of Patents and Trademarks

EXHIBIT B

Lau 1

340-10 1096
340 102
152238

SURVIVABLE RING NETWORK

Field of the Invention

The invention relates generally to a communications network. Specifically, it relates to a self-healing ring network.

Background of the Invention

A ring communications network is made up of nodes that are connected in tandem by a unidirectional communications path. Each node receives transmissions from the adjacent upstream node, and if the communication is destined for a downstream node, the communication is re-transmitted to the adjacent downstream node. Otherwise, each node transmits its own communications to the adjacent downstream node.

A drawback of such a network is that a break in the ring would prevent any node upstream of the break from communicating with any node downstream of the break. Similarly, the complete failure of a node would have the same effect as a break in the ring.

Many designs have been proposed to minimize these difficulties. The most common approach is to provide a second communications ring parallel to the first. In that case, a fault in one ring could be bypassed by transferring communications to the second ring. Alternatively, if the second ring transmitted in the opposite direction as the first, a break in both rings between two adjacent nodes could be remedied by the nodes on either side of the break looping back communications received on one ring onto the other ring. Such a system is described in McNeilly et al, U. S. Patent No. 3,652,798.

The main problem with such approaches is that the equipment required to detect and locate a fault, and then appropriately reconnect transmitters and receivers with the alternate ring, is complicated and costly.

Summary of the Invention

These and other difficulties are alleviated by my invention. A subrate multiplexed signal is utilized for ring communications. Each node has the capability of demultiplexing the main signal into its constituent subrates (channels), and channels destined for that node (local channels) are sent to receiving equipment within the node, while channels destined for downstream nodes (through channels) are multiplexed with originating local channels, and the resultant high level signal is transmitted to the adjacent downstream node. This process is simultaneously performed using identical equipment in the node for a second ring transmitting in the opposite direction. If a node detects a fault in an incoming line, an error signal is placed on all of the channels following the demultiplexing. The receiving equipment in each node includes a selector which monitors the communications arriving on each local channel from both rings. If an error signal is detected on a local channel, the selector selects the communication from the associated channel of the other ring to send to the receiver.

In this way, a break in both rings between two adjacent nodes will not cause a failure in the system, and no complicated fault locating and switching equipment is required to continue service. Similarly, the complete failure of a node will not destroy communications among the remaining nodes.

It should be noted that unlike prior survivable ring arrangements which maintain their ring characteristics following a fault, my invention ceases functioning as a ring if the ring is broken. However, as previously discussed, communications among the nodes is maintained following such a break. I therefore term my network a hybrid ring, since it normally operates as a ring, but does not operate as a ring following a break in the ring or the loss of a node.

Brief Description of the Drawing

FIG. 1 is a diagram of the hybrid ring network;

FIG. 2 is a diagram of the hybrid ring network with a break in both rings:

FIG. 3 is a diagram of a portion of a master/slave arrangement of two hybrid ring networks; and

FIG. 4 is a diagram of a portion of a master/master arrangement of two hybrid ring networks.

Detailed Description

An illustrative embodiment of my invention is depicted in FIG. 1. In discussing FIG. 1, it is helpful to have the background provided by the reference entitled "Draft of American National Standard for Telecommunications Digital Hierarchy Optical Interface Rates and Formats Specifications" dated December 11, 1987 as transmitted to the Secretariat of the Exchange Carriers Standards Association, T1 Committee - Telecommunications. This reference is incorporated herein by reference. My invention is an improvement to the basic communication methodology discussed in this reference. Node 1 comprises controllers 117 and 118 and selectors 119-121. Controller 117 is connected with ring 101, which carries signals in a clockwise direction, and controller 118 is connected with ring 100, which carries signals in a counterclockwise direction. Illustratively, the signals on each ring comprise six subrate channels, each of which is dedicated to communications between a pre-selected pair of basically identical nodes. Each node feeds three subrate receivers (not shown), which in the case of node 1 have lines 104, 107 and 110, respectively, as input.

The channel carrying communications between nodes 1 and 2 would be extracted from ring 101 by controller 117 (by demultiplexing the signal on ring 101), and sent to selector 119 over line 102. Controller 118 would extract the associated channel off ring 100 and send it to selector 119 over line 103. Selector 119 would select one of the signals arriving on lines 102 and 103,

based on the presence or absence of an error signal on either line. The selected signal would be sent to the receiver over line 104. A transmitter (not shown) would transmit two identical signals destined for node 2, one to controller 117 and one to controller 118, for reinsertion into the respective loops.

Channels associated with communications between nodes 3 and 1, and between nodes 4 and 1, would operate in a similar manner utilizing selectors 120 and 121, respectively. Controllers 117 and 118 then multiplex the three channels originating from node 1 with the three through channels, and transmit the resultant higher level signals on their associated loops (loop 101 toward node 4 and loop 100 toward node 2). In this way, each node has two redundant communications paths to each of the other nodes, both paths being continuously active.

The simplicity and elegance of my invention becomes apparent when a break occurs in the rings, as shown in FIG. 2. If rings 100 and 101 are broken between node 1 and node 4, two simultaneous activities take place which will preserve communications paths among all of the nodes.

Each node continuously monitors and evaluates the integrity of the multiplexed subrate signals arriving at the node. Illustratively, this could be accomplished by detecting the absence of a carrier signal in an analog signal environment, or the lack of any incoming signal in a digital environment. When node 1 recognizes major line fault 122 in ring 100, controller 118 inserts an error signal onto the six subrate channels. This could illustratively be accomplished by inserting a string of 1's on each channel in a digital environment. Node 4 performs the identical activity by similarly placing an error signal on the six subrate channels of ring 101. After these two relatively simple procedures take place, the ring network otherwise operates normally.

In node 1, selector 119 chooses line 102 because

line 103 has an error signal on it (designated by dashed ~~bold~~ line 103). Similarly, selector 120 selects line 105 because line 106 has an error signal, and selector 121 selects line 108 because line 109 contains an error signal. The three through channels on ring 100 that contain error signals are then multiplexed with the three local channels that now have valid data originating from node 1 and the higher level signal is transmitted to node 2 over ring 100.

Because the higher level signal arriving at node 2 on ring 100 appears normal, controller 148 demultiplexes the higher level signal into its six subrate channels, three of which terminate at node 2. The first local channel contains communications from node 3 to node 2. An error signal was generated on this channel at node 1. Controller 148 sends this error signal to selector 149 via line 133. Selector 149 therefore selects line 132 from controller 147, containing traffic from node 3 to node 2 over ring 101, which is not affected by break 122.

Similarly, selector 150 recognizes the error signal on line 136 and selects line 135. Selector 151 receives communications from node 1 over line 139 from ring 100 and receives an error signal over line 138 from ring 101. Therefor, selector 151 would select line 139.

Communications from node 1 to node 3 and from node 1 to node 4 are multiplexed from lines 144 and 146 by controller 148. Communications from node 4 to node 3 are also multiplexed from line 145 by controller 148, thereby passing along the error signal contained therein to node 3 over ring 100.

Each node operates in the above manner to insure continuity of communications among the nodes following a ring failure; or, as in the case of break 122, a multiple ring failure between two adjacent nodes. If a node fails, the same process will maintain communications among the remaining nodes.

It should be readily apparent that other

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techniques could be employed without departing from the scope of my invention, such as designating the destination node within each message, and having each node read the destination of each message passing through the node, and selecting messages destined for itself.

FIG. 3 depicts an embodiment of my invention wherein two ring sets are joined in a dual-ring configuration at a common node (gateway node). Ring arrangement A is designated the master ring and ring arrangement B is designated the slave ring. Controller 405 of the gateway node extracts a pre-selected subrate channel off ring 401 and sends the extracted channel to selector 407 over line 417. Controller 406 sends a similarly pre-selected subrate channel from ring 402 to selector 407 over line 418. Selector 407 chooses a non-error signal line for insertion onto slave rings 403 and 404 via line 419. In this way, any one break in the master rings 401 and 402 will not prevent a valid subrate channel from being inserted onto slave ring 403.

Controllers 409 and 410 insert and extract communications on rings 403 and 404, respectively, and selector 408 chooses a non-error signaled input. If, illustratively, break 422 occurs on rings 403 and 404, controllers 412 and 410 will insert error signals on associated subrate paths, and controllers 409, 413, 414 and 415 would operate as if no break occurred. Selectors 408, 411 and 416 would select inputs that do not contain error signals. It should be readily apparent that a two-ring break in either the master ring or the slave ring would not result in the loss of communications between any two nodes. However, simultaneous breaks in both the master and slave rings would result in selected communications losses.

FIG. 4 depicts two interrelated rings that can withstand simultaneous breaks in both rings without loss of communications between any two nodes, by employing a master-master relationship. Instead of one gateway node

connecting the two rings, one node on each master ring is connected by link 519. Controllers 505 and 506 send a subrate communications channel to selector 507, and controllers 509 and 510 send a subrate communications channel to selector 508. If there is a break in ring A, selector 507 will select the non-error signal communication from line 513 or line 514 and transmit to ring B via line 517, and similarly, if there is a break in ring B, selector 508 will select the non-error signal communication from line 521 or 522 and transmit to ring A via line 518. It should be readily apparent that simultaneous breaks in both ring A and ring B will not result in the loss of communications between any two nodes.

My invention will work regardless of whether the ring networks are copper or fiber, and regardless of what higher rates and subrates are utilized. The dual ring embodiment depicted on FIG. 3 is most beneficially suited to multiple levels of subrating. For instance, in FIG. 3, if ring A carried a signal which could be demultiplexed into two subchannels by controllers 405 and 406, one subchannel could be sent to ring B by selector 407. Controllers 409-410 and 412-415 on ring B would then further demultiplex the subchannel for communications terminating at nodes on ring B.

Those ordinarily skilled in the art could make obvious modifications to my invention without departing from its scope.

What is claimed is:

1. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated subrate receivers, the improved node comprising

monitoring means, associated with the rings, for evaluating the integrity of the multiplexed subrate communications on each of the associated rings, and

insertion means, associated with the demultiplexers and said monitoring means, for inserting an error signal on designated ones of the subrate communications in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on at least one of the associated rings.

2. In the communications network of claim 1, the improved node further comprising selector means associated with the demultiplexers for selecting, in response to the detection of said error signal on one of the subrate communications, another of the subrate communications that does not contain said error signal.

3. In the communications network of claim 1, the improved node wherein the multiplexers multiplex selected subrate communications containing said error signal into a multiplexed subrate communication for transmission onto the associated rings.

4. A communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction

and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each of said nodes including subrate transmitters and subrate receivers and further comprising:

monitoring means for evaluating the integrity of the multiplexed subrate communications on each of the associated rings,

means for demultiplexing the multiplexed subrate communications on the associated ring into subchannels, wherein at least one of said subchannels is sent to a corresponding receiver,

insertion means associated with said demultiplexing means to insert an error signal on each of said subchannels in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on one of the associated rings,

selector means associated with said demultiplexing means for selecting, in response to the detection of said error signal on one of the subchannels, one of the other subchannels, and

multiplexing means for multiplexing subchannels and inserting multiplexed subrate communications onto the associated ring.

5. A communications network having a first grouping of nodes interconnected by a first ring arrangement, a second grouping of nodes interconnected by a second ring arrangement, each ring arrangement conveying multiplexed subrate communications in a first direction from node to node and conveying multiplexed subrate communications in a second direction from node to node, and each node comprises subrate transmitters with associated multiplexers and demultiplexers with associated receivers, and wherein

each node comprises

monitoring means associated with its ring arrangement for evaluating the integrity of the multiplexed subrate communications on the associated ring,

insertion means, associated with its demultiplexers and its monitoring means, for inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed subrate communications on its said associated ring arrangement, and

selector means, associated with its demultiplexers, for selecting, in response to the detection of said error signal on a subrate communication, a subrate communication that does not contain an error signal, and

wherein a preselected node of the first ring arrangement comprises;

means for directing at least one subrate communication to the second ring arrangement and corresponding subrate communications from the second ring arrangement for multiplexing onto multiplexed subrate communications on the first ring arrangement.

6. The network of claim 5 wherein said subrate communication directed to the second ring arrangement is received by a preselected node of the second ring arrangement for multiplexing into multiplexed subrate communications around the second ring arrangement,

and wherein the subrate communications directed to the first ring arrangement originates at said preselected node of the second ring arrangement.

7. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated receivers, an improved

method associated with each node comprising the steps of

evaluating the integrity of the multiplexed subrate communications on each of said associated rings with monitoring means, and

inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed communications on at least one of said associated rings.

8. The method as recited in claim 7 further comprising the step of selecting, response to the detection of said error signal on said at least one of the subrate communications, another of the subrate communications that does not contain an error.

Lau 1

Abstract of the Disclosure

A survivable ring network is disclosed that can withstand a cut link or failed node, without the need for a central controller or protection switching among links. The disclosed invention comprises two rings carrying identical multiplexed node-to-node communications in opposite directions. When a system error is detected in a downstream node, error signals are inserted in all subrate channels. Each subrate channel receiver receives identical communications from each ring. If one subrate channel has an error signal, the receiver selects the alternate channel.

EXHIBIT C

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
07/152,238	02/04/88	LAU C	1

JAMES W. FALK
BELL COMMUNICATIONS RESEARCH, INC.,
290 WEST MOUNT PLEASANT AVE.
LIVINGSTON, NJ 07039

EXAMINER	
CHIN, W	
ART UNIT	PAPER NUMBER
263	3

DATE MAILED: 10/06/88

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

☒ This application has been examined ☐ Responsive to communication filed on ______ ☐ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), — days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. ☒ Notice of References Cited by Examiner, PTO-892.
2. ☒ Notice re Patent Drawing, PTO-948.
3. ☒ Notice of Art Cited by Applicant, PTO-1449
4. ☐ Notice of informal Patent Application, Form PTO-152
5. ☒ Information on How to Effect Drawing Changes, PTO-1474
6. ☒ List of Bonded Draftsmen

Part II SUMMARY OF ACTION

1. ☒ Claims 1-8 are pending in the application.
   Of the above, claims ______ are withdrawn from consideration.
   ______ have been cancelled.
2. ☐ Claims ______ are allowed.
3. ☐ Claims ______ are rejected.
4. ☒ Claims 1-8 are rejected.
   ______ are objected to.
5. ☐ Claims ______ are subject to restriction or election requirement.
6. ☐ Claims ______
7. ☒ This application has been filed with informal drawings which are acceptable for examination purposes until such time as allowable subject matter is indicated.
8. ☐ Allowable subject matter having been indicated, formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on ______. These drawings are ☐ acceptable; ☐ not acceptable (see explanation).
10. ☐ The ☐ proposed drawing correction and/or the ☐ proposed additional or substitute sheet(s) of drawings, filed on ______ has (have) been ☐ approved by the examiner. ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed ______, has been ☐ approved. ☐ disapproved (see explanation). However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections MUST be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
12. ☐ Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received ☐ been filed in parent application, serial no. ______; filed on ______.
13. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

PTOL-326 (Rev. 7-82) EXAMINER'S ACTION

1. The drawings are objected to because the figures lack descriptive labels. Correction is required.

2. Applicant is required to submit a proposed drawing correction in response to this Office action. However, correction of the noted defect can be deferred until the application is allowed by the examiner.

3. Claims 1-8 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claim 1, page 8, lines 10-11, "the improved node" lacks antecedent basis. Claim 1, page 8, line 12, it is unclear what "the rings" is referring to, as there is no clear antecedent for this terminology.

Claim 1, page 8, lines 14 and 20 respectively, it is unclear what structure "the associated rings" is referring to. Claim 4, page 9, lines 6-7, it is unclear what "the associated rings" are, as it is unclear as to what the rings are being associated with and there is no clear antecedent for a first and second ring only. Claim 4, page 9, lines 10-11, it is unclear if "a corresponding receiver" is meant to refer to one of the subrate receivers previously recited. Claims 5-8 are rejected for similar reasons as those set forth above.

4. Claims 1-8 would be allowable if rewritten or amended to overcome the rejection under 35 U.S.C. 112.

5. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Prior art cited is typical of prior fault recovery tech-

niques used in multiple ring communication systems.

6. Any inquiry concerning this communication should be directed to Wellington Chin at telephone number 703-557-3374.

W. Chin:vj

703-557-3374

10-03-88 KL

Douglas W. Olms

DOUGLAS W. OLMS
PRIMARY EXAMINER
GROUP 263

TO SEPARATE, HOLD TOP AND BOTTOM EDGES, SNAP–APART AND DISCARD CARBON

FORM PTO-892 (REV. 3-78) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

SERIAL NO. 152,238 | GROUP ART UNIT 263 | ATTACHMENT TO PAPER NUMBER 3

NOTICE OF REFERENCES CITED

APPLICANT(S) Lau

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A	4542502	8/85	Levinson et al	370	88	
	B	4683563	7/87	Rouse et al	370	16	
	C	4710915	12/87	Kitahara	370	16	
	D						
	E						
	F						
	G						
	H						
	I						
	J						
	K						

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PERTINENT PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

R

S

T

U

EXAMINER WELLINGTON CHIN wc | DATE 9/25/88

* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05 (a).)

PTO - 948
(Rev. 8-82)

GROUP 263

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ATTACHMENT TO PAPER NUMBER 3

S.N. 152238

NOTICE OF PATENT DRAWINGS OBJECTION

Drawing Corrections and/or new drawings may only be submitted in the manner set forth in the attached letter, "Information on How to Effect Drawing Changes" PTO-1474.

A. ☑ The drawings, filed on 2-4-88, are objected to as informal for reason(s) checked below:

1. ☐ Lines Pale.
2. ☐ Paper Poor.
3. ☐ Numerals Poor.
4. ☐ Lines Rough and Blurred.
5. ☐ Shade Lines Required.
6. ☐ Figures Must be Numbered.
7. ☐ Heading Space Required.
8. ☐ Figures Must Not be Connected.
9. ☐ Criss-Cross Hatching Objectionable.
10. ☐ Double-Line Hatching Objectionable.
11. ☐ Parts in Section Must Be Hatched.
12. ☑ Solid Black Objectionable. FIG. 2
13. ☐ Figure Legends Placed Incorrectly.
14. ☐ Mounted Photographs.
15. ☐ Extraneous Matter Objectionable. [37 CFR 1.84 (1)]
16. ☐ Paper Undersized; either 8½" x 14", or 21.0 cm. x 29.7 cm. required.
17. ☐ Proper A4 Margins Required:
    - ☐ TOP 2.5 cm.
    - ☐ RIGHT 1.5 cm.
    - ☐ LEFT 2.5 cm.
    - ☐ BOTTOM 1.0 cm.
18. ☐ Other:

B. ☑ The drawings, submitted on 2-4-88, are so informal they cannot be corrected. New drawings are required. Submission of the new drawings MUST be made in accordance with the attached letter.

EXHIBIT D

MAIL ROOM JAN 6 1989 45 PAT. & TRADEMARK OFF.

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Chi-Leung Lau
Case 1
Serial No. 152,238 Filed February 4, 1988
Group Art Unit 263
Examiner W. Chin
Title Survivable Ring Network

RECEIVED
JAN 10 1989
GROUP 260

THE COMMISSIONER OF PATENTS AND TRADEMARKS
WASHINGTON, D. C. 20231

SIR:

In response to the Office action dated October 6, 1988 (application paper No. 3), please amend the above-identified application as follows:

IN THE SPECIFICATION

Page 5, line 1, replace "bold" with --dashed--.

IN THE CLAIMS

Please amend claims 1, 3, 4, 5, 7 and 8 as follows:

1. (Amended) In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated subrate receivers, an [the] improved node comprising

monitoring means, associated with the first ring and the second ring [rings], for evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring, respectively [each of the associated

rings], and

A1

insertion means, associated with the demultiplexers and said monitoring means, for inserting an error signal on designated ones of the subrate communications in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on the first ring or the second ring or both the first ring and the second ring [at least one of the associated rings].

3. (Amended) In the communications network of claim 1, the improved node wherein the multiplexers multiplex selected subrate communications containing said error signal into a multiplexed subrate communication for transmission onto the first ring or the second ring or both in correspondence to said detection of said error signal [the associated rings].

A2

4. (Amended) A communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each of said nodes including subrate transmitters and subrate receivers and further comprising:

monitoring means, associated with the first ring and the second ring, for evaluating the integrity of the multiplexed subrate communications on the associated first ring and the associated second ring, respectively [each of the associated rings],

means for demultiplexing the multiplexed subrate communications on the associated first ring and the associated second ring into subchannels wherein at least one of said subchannels is sent to [a] one of the corresponding receivers [receiver],

insertion means associated with said demultiplexing means to insert an error signal on each of

said subchannels in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on [one] the associated first ring or the associated second ring or both the associated first ring and the associated second ring [of the associated rings],

selector means associated with said demultiplexing means for selecting, in response to the detection of said error signal on one of the subchannels, one of the other subchannels, and

multiplexing means for multiplexing subchannels and inserting multiplexed subrate communications onto the associated first ring and the associated second ring, respectively.

5. (Amended) A communications network having a first grouping of nodes interconnected by a first ring arrangement, a second grouping of nodes interconnected by a second ring arrangement, each ring arrangement conveying multiplexed subrate communications in a first direction from node to node and conveying multiplexed subrate communications in a second direction from node to node, and each node includes [comprises] subrate transmitters with associated multiplexers and demultiplexers with associated receivers, and wherein

each node comprises

monitoring means, associated with [its] the ring arrangement connected to said each node, for evaluating the integrity of the multiplexed subrate communications on [the] said associated ring arrangement,

insertion means, associated with its demultiplexers and its monitoring means, for inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed subrate communications on its said associated ring arrangement, and

selector means, associated with its demultiplexers, for selecting, in response to the detection of said error signal on a subrate communication, a subrate

communication that does not contain an error signal, and

wherein a preselected node of the first ring arrangement comprises;

means, connected to the first ring arrangement and the second ring arrangement, for directing at least one subrate communication to the second ring arrangement and corresponding subrate communications from the second ring arrangement for multiplexing onto multiplexed subrate communications on the first ring arrangement.

7. (Amended) In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated receivers, an improved method associated with each node comprising the steps of

evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring [each of said associated rings] with monitoring means associated with both the first ring and the second ring, and

inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed communications on the first ring or the second ring or both the first ring and the second ring [at least one of said associated rings].

8. (Amended) The method as recited in claim 7 further comprising the step of selecting, in response to the detection of said error signal on said at least one of the subrate communications, another of the subrate communications that does not contain an error.

Remarks

Claims 1-8 are pending in this application. As a result of the instant Office action, claims 1-8 stand rejected under 35 U.S.C. 112, second paragraph. However, the Examiner did indicate that claims 1-8 "would be allowable if rewritten or amended to overcome the rejection under 35 U.S.C. 112."

With respect to particular claims, the Examiner sets forth the following reasons as the basis for the rejection.

Claim 1

(a) "the improved node" on page 8, lines 10-11, lacks antecedent basis;

(b) on page 8, line 12, it is unclear what "the rings" is referring to, as there is no clear antecedent for this terminology; and

(c) on page 8, lines 14 and 20, respectively, it is unclear what structure "the associated rings" is referring to.

The Applicant has rewritten claim 1 to overcome the Examiner's reasons for rejecting claim 1. In particular, claim 1 now recites "an improved node" thereby indicating the first appearance of this structure in the claim. In addition, claim 1 now explicitly calls for "the first ring and the second ring" instead of "rings" so as to clarify the interrelationship among the various claim elements.

Claim 3, which is dependent on claim 1, has been amended to recite that the error signal is multiplexed for transmission onto "the first ring or second ring in correspondence to said detection of said error signal".

Claim 4

(a) on page 9, lines 6-7, it is unclear what "the associated rings" are, and it is unclear as to what the rings are associated with and there is no clear antecedent for the first and second ring only.

(b) on page 9, lines 10-11, it is unclear if "a corresponding

receiver" is meant to refer to one of the subrate receivers previously recited.

The Applicant has amended claim 4 in a manner similar to claim 1 in that the reasons for rejecting claim 4 are substantially the same used to reject claim 1. Claim 4 now calls for "the first associated ring" and "the second associated ring" in place of the less explicit term "rings".

Claims 5-8 have been rejected by the Examiner "for similar reasons for those set forth above" with respect to the rejections of claims 1 and 4. Accordingly, the Applicant has amended independent claims 5 and 7 in substantially the same manner as claims 1 and 4 to overcome the Examiner's rejections and place these claims in condition for allowance. In particular, claim 5 has been amended to clarify that each node has a monitoring means associated with the ring arrangement connected to each particular node and that the means for directing is connected to both the first ring arrangement and the second ring arrangement. With respect to claim 7, this claim now calls for "evaluating the integrity ... on the first ring and the second ring with monitoring means associated with both the first ring and the second ring", thereby clarifying any ambiguity in a manner commensurate with claim 1. Also, claim 8 has been amended for clarity in a manner commensurate with claim 2.

Finally, the drawing was objected to because (i) the figures lacked descriptive labels and (ii) bold black lines were used in FIG. 2 to differentiate lines carrying error signals from lines without error signals. The Applicant proposes that the bold lines in FIG. 2 be replaced with dashed lines, as shown on the enclosed, red-inked marked FIG. 2. The specification, on page 5, line 1, has been changed to reflect this change in FIG. 2. Does the Examiner concur with this proposed change? In addition, the Applicant requires guidance with respect to the objection on the basis that the figures lack descriptive labels. The Applicant has perused each FIGURE and believes all required descriptive labels/reference numerals have been clearly

identified, and there is correspondence among the specification, the drawing and the claims. If the Examiner believes correction is still required, would the Examiner please amplify on this remark and point out which FIGURES and the elements in these FIGURES that lack descriptive labels?

It is respectfully requested that claims 1-8 of this application be reconsidered and reexamined and that this application now passed to issue.

Respectfully submitted,
Chi-Leung Lau

By John T. Peoples
John T. Peoples, Attorney
Reg. No. 28250
201-740-6155

Bell Communications Research, Inc.

Date: JAN 4 1989

Enclosure:
Red-inked marked FIG. 2

MAIL ROOM
JAN 6 1989
PAT. & TRADEMARK OFF.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Chi-Leung Lau

CASE 1
SERIAL NO. 152,238 FILED February 4, 1988
GROUP ART UNIT 263
EXAMINER W. Chin
TITLE Survivable Ring Network

RECEIVED
JAN 10 1989
GROUP 260

THE COMMISSIONER OF PATENTS AND TRADEMARKS
WASHINGTON, D.C. 20231

SIR:

Enclosed is an amendment in the above-identified application.

[x] No additional fee is required, as shown below.
[ ] A check in the amount of $____________ is attached to cover the fee, which has been calculated as shown below.

CLAIMS AS AMENDED						
(1)	(2) CLAIMS REMAINING AFTER AMENDMENT	(3)	(4) HIGHEST NUMBER PREVIOUSLY PAID FOR	(5) PRESENT EXTRA	(6) RATE	(7) ADDITIONAL FEE
TOTAL CLAIMS FOR FEE PURPOSES	8	MINUS	20	0	x $12	0
INDEPENDENT CLAIMS	4	MINUS	3	0	x $34	0
MULTIPLE CLAIM(S) FIRST PRESENTED WITH THIS AMENDMENT	NO [x]	YES [ ]			IF YES, +$110	0
TOTAL ADDITIONAL FEE FOR THIS AMENDMENT →						$ 0

In the event of any non-payment or improper payment of a required fee, the Commissioner is authorized to charge deposit account 02-1820 as required to correct the error.

JTPeoples/la
Attorney for Applicant(s)

Date: JAN 4 1989

Bell Communications Research, Inc.
290 West Mount Pleasant Avenue - Room 2E-304
Livingston, NJ 07039

PT. 16 8/87 (rdp)

I hereby certify that this correspondence is being deposited with the United States Postal Service [illegible] in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, D.C. [illegible]
JAN 4 1989
JAN 4 1989
[illegible]

EXHIBIT E

An American National Standard

Acknowledged as An American National Standard
July 8, 1988

IEEE Standard Dictionary of Electrical and Electronics Terms

Fourth Edition

er

ANSI/IEEE Std 100-1988
Fourth Edition

IEEE Standard Dictionary of Electrical and Electronics Terms

Frank Jay
Editor in Chief

J. A. Goetz
Chairman
Standards Coordinating Committee on Definitions (SCC 10)

Membership

Published by
The Institute of Electrical and Electronics Engineers, Inc
New York, NY

Library of Congress Catalog Number 88-082198
ISBN: 1-55937-000-9

November 3, 1988

SH12070

multiple-unit electric locomotive. A locomotive composed of two or more multiple-unit electric motive-power units connected for simultaneous operation of all such units from a single control station. *Note:* A prefix diesel-electric, turbine-electric, etcetera, may replace the word electric. *See:* **electric locomotive.** 328

multiple-unit electric motive-power unit. An electric motive-power unit arranged either for independent operation or for simultaneous operation with other similar units (when connected to form a single locomotive) from a single control station. *Note:* A prefix diesel-electric, gas-electric, turbine-electric, etcetera, may replace the word electric. *See:* **electric locomotive.** 328

multiple-unit electric train. A train composed of multiple-unit electric cars. *See:* **electric motor car.** 328

multiple-unit tube. *See:* **multiple tube (or valve).**

multiplex (communication) (data transmission). To interleave or simultaneously transmit two or more messages on a single channel. 59

multiplexer (supervisory control, data acquisition, and automatic control). (1) A device that allows the interleaving of two or more signals to a single line or terminal. (2) A device for selecting one of a number of inputs and switching its information to the output. 570

multiplexing (modulation systems) (data transmission). The combining of two or more signals into a single wave (the multiplex wave) from which the signals can be individually recovered. 59

multiplex lap winding (rotating machinery). A lap winding in which the number of parallel circuits is equal to a multiple of the number of poles. 63

multiplexor (hybrid computer linkage components). An electronic multiposition switch under the control of a digital computer, generally used in conjunction with an analog-to-digital converter (ADC), that allows for the selection of any one of a number of analog signals (up to the maximum capacity of the multiplexor), as the input to the ADC. A device that allows the interleaving of two or more signals to a single line or terminus. 10

multiplex printing telegraphy. That form of printing telegraphy in which a line circuit is employed to transmit in turn one character (or one or more pulses of a character) for each of two or more independent channels. *See:* **frequency-division multiplexing; time-division multiplexing; telegraphy.** 328

multiplex radio transmission. The simultaneous transmission of two or more signals using a common carrier wave. *See:* **radio transmission.** 111

multiplex wave winding (rotating machinery). A wave winding in which the number of parallel circuits is equal to a multiple of two, whatever the number of poles. 163

multiplication factor (k)(1)(power operations). A measure of the change in the neutron population in a reactor core from one generation to the subsequent generation. *See:* **effective multiplication factor; infinite multiplication factor.** 516

(2) (multiplier type of valve or tube) (thermionics). The ratio of the output current to the primary emission current. *See:* **electron emission.** 244, 190

multiplicative array antenna system. A signal-processing antenna system consisting of two or more receiving antennas and circuitry in which the effective angular response of the output of the system is related to the product of the radiation patterns of the separate antennas. 111

multiplier (1) (general). A device that has two or more inputs and whose output is a representation of the product of the quantities represented by the input signals. 210

(2) (analog computers). In an analog computer, a device capable of multiplying one variable by another. 9

(3) (linearity). *See:* **constant multiplier; normal linearity; servo multiplier.**

multiplier, constant (computing systems). A computing element that multiplies a variable by a constant factor. *See:* **electronic analog computer; multiplier (linearity).** 9, 10

multiplier, electronic. An all-electronic device capable of forming the product of two variables. *Note:* Examples are a time-division multiplier, a square-law multiplier, an amplitude-modulation-frequency-modulation (AM-FM) multiplier, and a triangular-wave multiplier. *See:* **electronic analog computer.** 9

multiplier, four-quadrant (analog computer). A multiplier in which operation is unrestricted as to the sign of both of the input variables. 10

multiplier, one-quadrant. A multiplier in which operation is restricted to a single sign of both input variables. *See:* **electronic analog computer.** 9

multiplier phototube. A phototube with one or more dynodes between its photocathode and output electrode. *See:* **amplifier; photocathode.** 125, 117

multiplier potentiometer (analog computers). Any of the ganged potentiometers of a servo multiplier that permit the multiplication of one variable by a second variable. 9

multiplier section, electron (electron tubes). *See:* **electron multiplier.**

multiplier servo. An electromechanical multiplier in which one variable is used to position one or more ganged potentiometers across which the other variable voltages are applied. *See:* **electronic analog computer; multiplier (linearity).** 9, 10

multiplier, two-quadrant. A multiplier in which operation is restricted to a single sign of one input variable only. *See:* **electronic analog computer.** 9, 10

multiplying-digital-to-analog converter (MDAC) (hybrid computer linkage components). *See:* **digital-to-analog multiplier (DAM).**

multipoint circuit (data transmission). A circuit interconnecting several stations. 59

multipoint connection (data communication). A configuration in which more than two stations are connected to a shared communications channel. 12

multipole fuse (1) (power switchgear). *See:* **pole (pole unit) (of a switching device or fuse) Second note.** 103

EXHIBIT F

DICTIONARY OF COMPUTERS, INFORMATION PROCESSING, AND TELECOMMUNICATIONS

2ND EDITION

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10 9 8 7 6 5 4 3 2 1

more computer processes concurrently.

multiple precision: pertaining to the use of two or more computer words to represent a number in order to enhance precision. (A) (B)

multiple programming: programming of a computer by permitting two or more arithmetical or logical operations to be executed simultaneously.

multiple punching: punching more than one hole in the card column by several keystrokes, usually in order to extend the character set of the punch. (E)

multiple recording medium word processing equipment: word-processing equipment that can operate on two or more recording media. (D)

multiple routing: a method of sending a message where more than one destination is specified in the header of the message.

multiple system: a computer system containing two or more central processing units with input-output units and other hardware units that are related and interconnected for simultaneous operation.

multiple-task management: managing the performance of more than one data-processing task at a time.

multiple utility: a utility that permits one to three utility operators to be performed simultaneously.

multiplex

(1) to interleave or simultaneously transmit two or more messages on a single channel. (A).

(2) the process or equipment for combining a number of individual channels into a common spectrum or into a common bit stream for transmission. (F)

multiplex aggregate bit rate: in a time division multiplexing system, the sum of the bit rates of the separate input channels plus the overhead bits needed by the multiplexing process.

multiplex data terminal: a unit that modulates and/or demodulates data between two or more input-output units and a data transmission link.

multiplexed channel: a channel for carrying simultaneously a number of message signals that have been combined by multiplexing them on a carrier signal.

multiplexed operation: a simultaneous operation sharing the use of a common unit of a system so that it can be considered an independent operation.

multiplexed traffic: message signals that have been converted into a form and combined so that hundreds or thousands of signals can be transmitted down the same transmission path simultaneously.

multiplexer (M) (MPLX) (MPLXR) (MPX) (MUL) (MUX): a device capable of interleaving the events of two or more activities or capable of distributing the events of an interleaved sequence to the respective activities. (A) see *data multiplexer*. (E)

multiplexer channel (MXC): a channel designed to operate with a number of I/O devices simultaneously. Several I/O devices can transfer records at the same time by interleaving items of data. see also *block multiplexer channel, byte multiplexer channel.*

multiplexer polling: a technique of polling or voting that permits each remote multiplexer to query the terminals connected to it.

multiplexer simulation: a testing program which simulates the activities of the multiplexer.

multiplexing

(1) in data transmission, a function that permits two or more data sources to share a common transmission medium such that each data

EXHIBIT G

United States Patent [15] **3,652,798**

McNeilly et al. [45] **Mar. 28, 1972**

[54] **TELECOMMUNICATION SYSTEM**

[72] Inventors: **Joseph Hood McNeilly,** Harlow; **Ryszard Kitajewski,** Nazeing, both of England

[73] Assignee: **International Standard Electric Corporation,** New York, N.Y.

[22] Filed: **June 8, 1970**

[21] Appl. No.: **44,396**

[30] **Foreign Application Priority Data**

July 28, 1969 Great Britain 37,764/69

[52] **U.S. Cl.** ....**179/15 AL**
[51] **Int. Cl.** **H04j 3/00**
[58] **Field of Search** ....179/15 AL, 175.31

[56] **References Cited**

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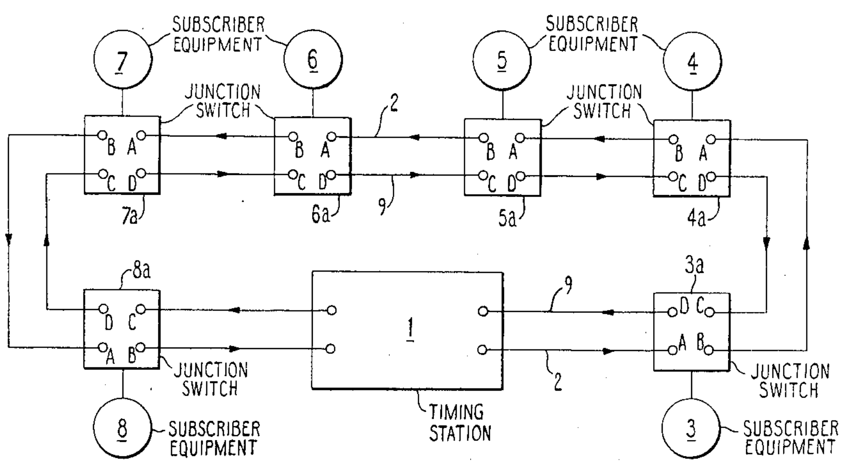
[57] **ABSTRACT**

A timing station provides time division multiplex channel signals on a first closed loop unidirectional transmission line interconnective in tandem subscriber stations, each of which may gain access to an unused channel signal for communication with an idle subscriber station. To protect against failure of the entire system due to a break in the line or failure in one of the subscriber stations, a second closed loop unidirectional transmission line is connected to all stations transmitting signals in a direction opposite to that on the first line. Each subscriber station can detect an error and transfer the communication signals on the first line to the second line. The subscriber station before the break transfers the communication signal to the second line and the subscriber station after the break transfers the communication signals back to the first line to form a new, but continuous closed loop. When communication signals are on the second line and a fault occurs, the transfer of communication signals will be similarly performed to provide still another new, but continuous closed loop by passing the fault. Two embodiments to detect a fault and control the transfer of communication between the two lines are disclosed.

9 Claims, 11 Drawing Figures



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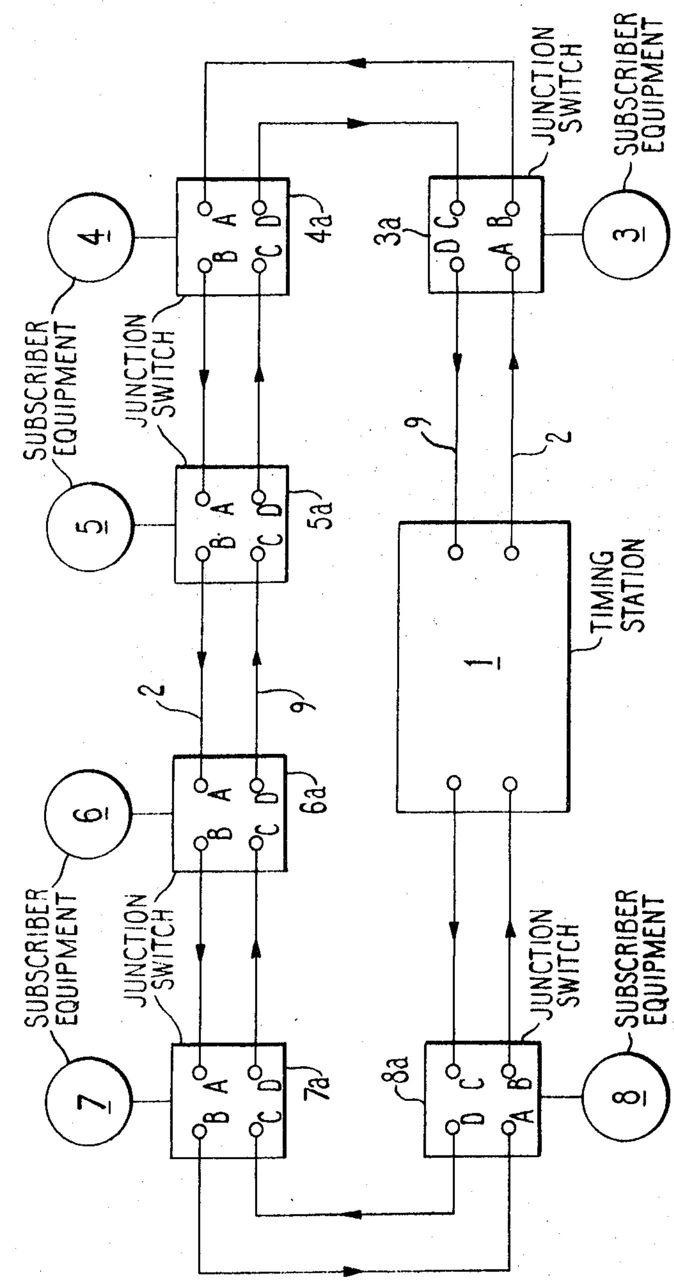

FIG.1

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PATENTED MAR 28 1972 3,652,798

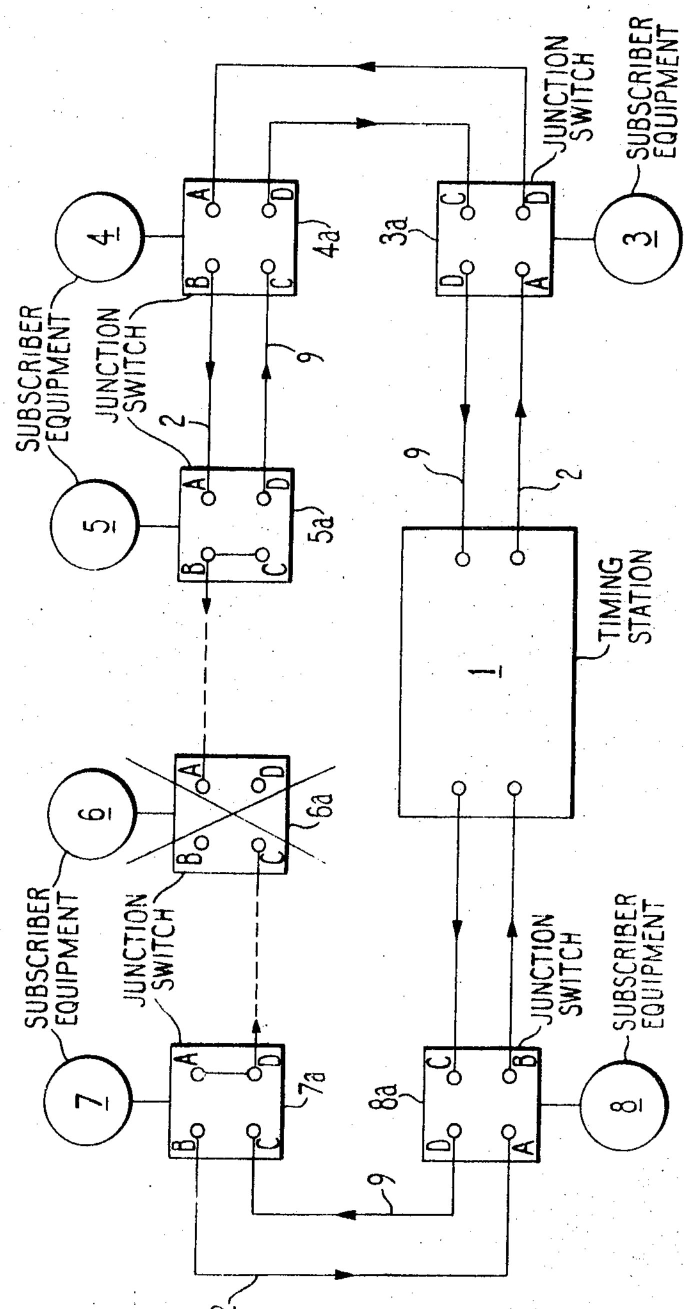

FIG.2

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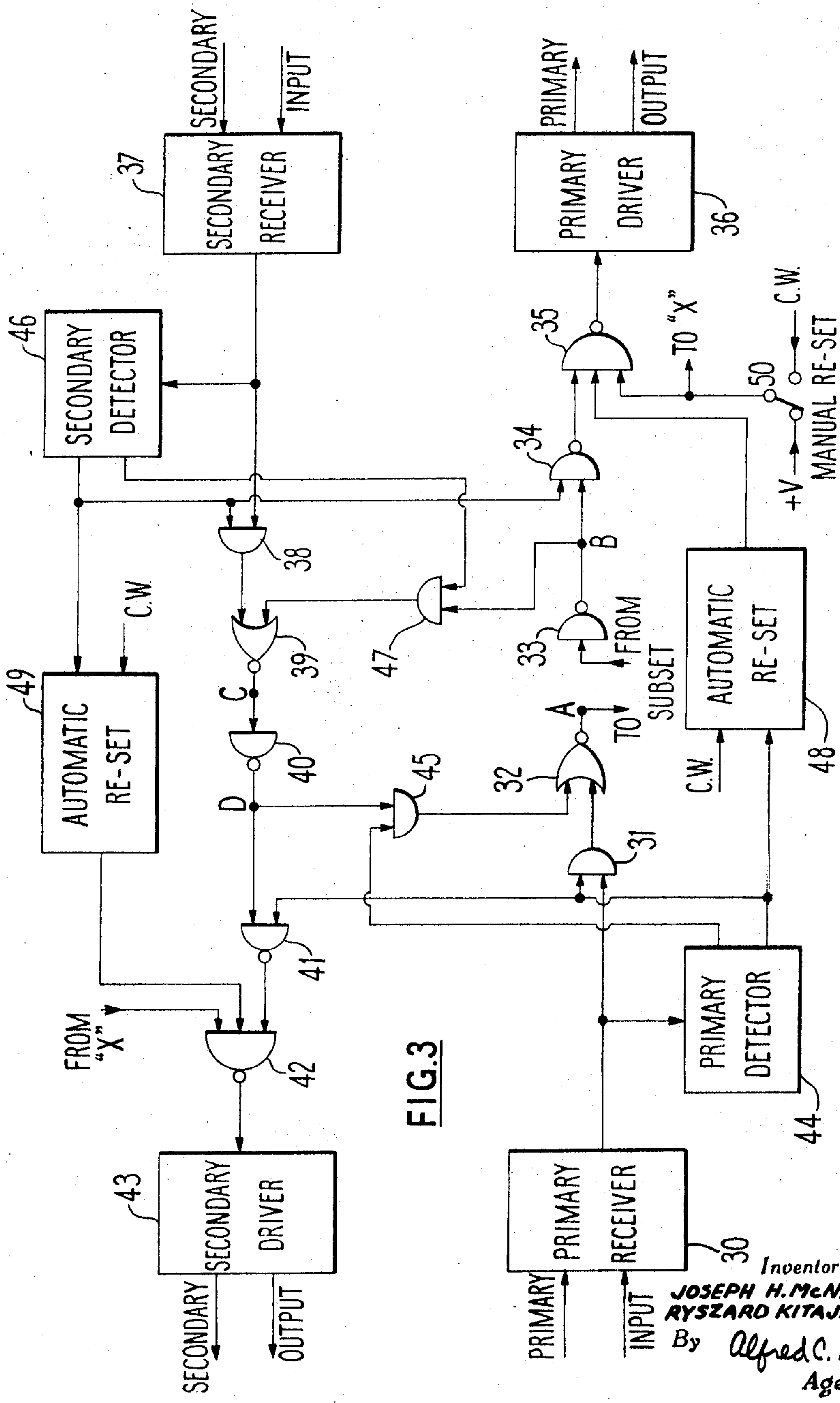

FIG.3

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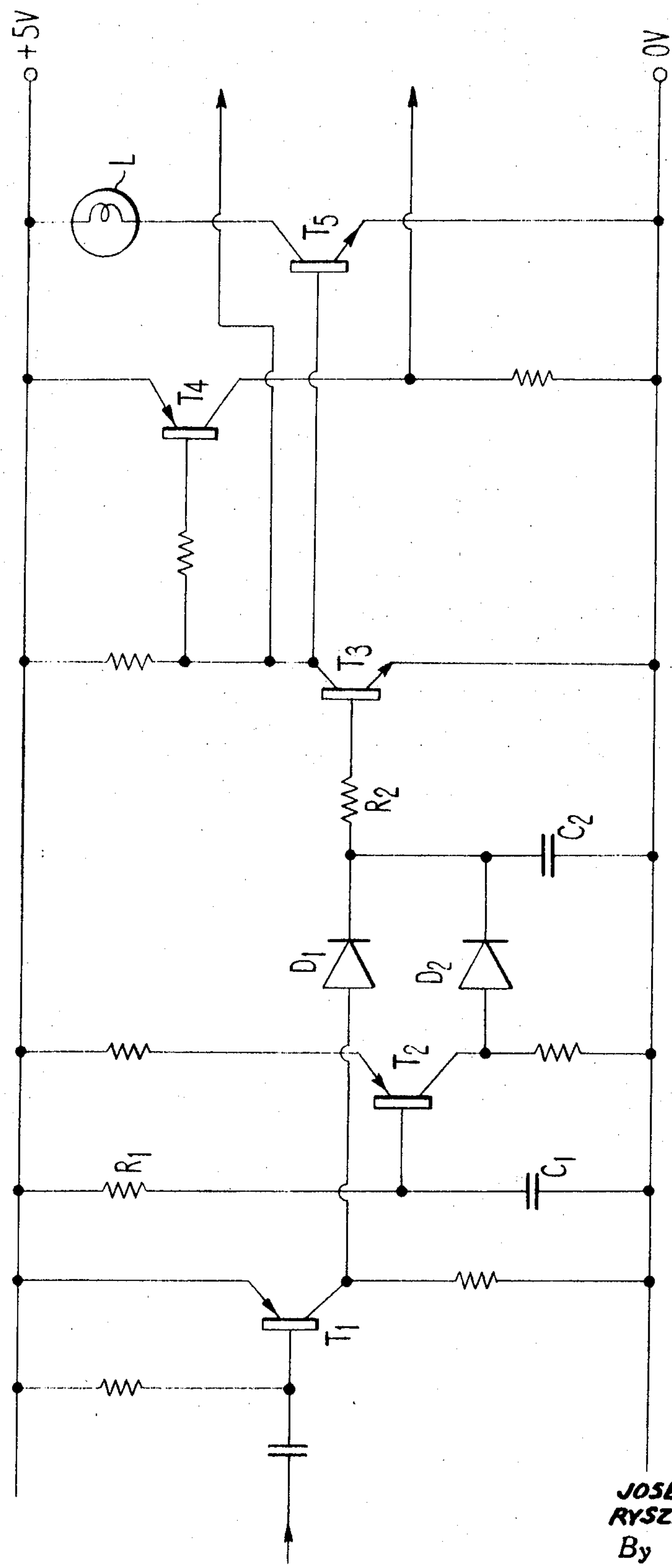

FIG.4

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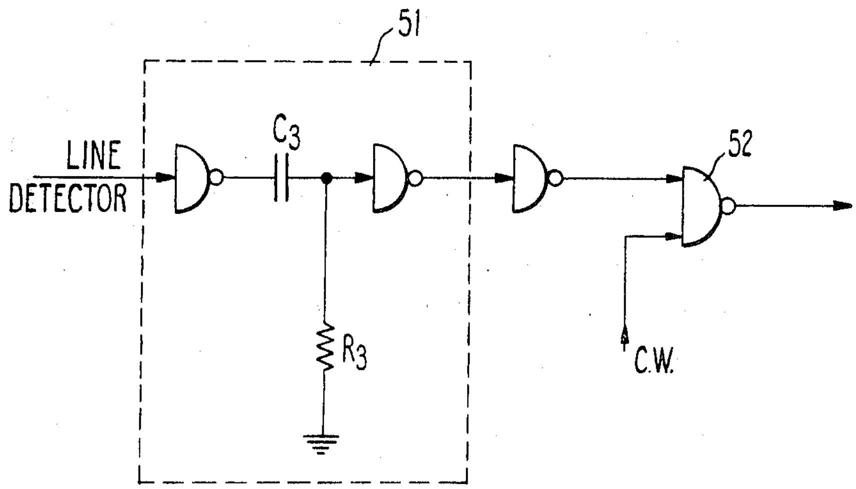

FIG. 5

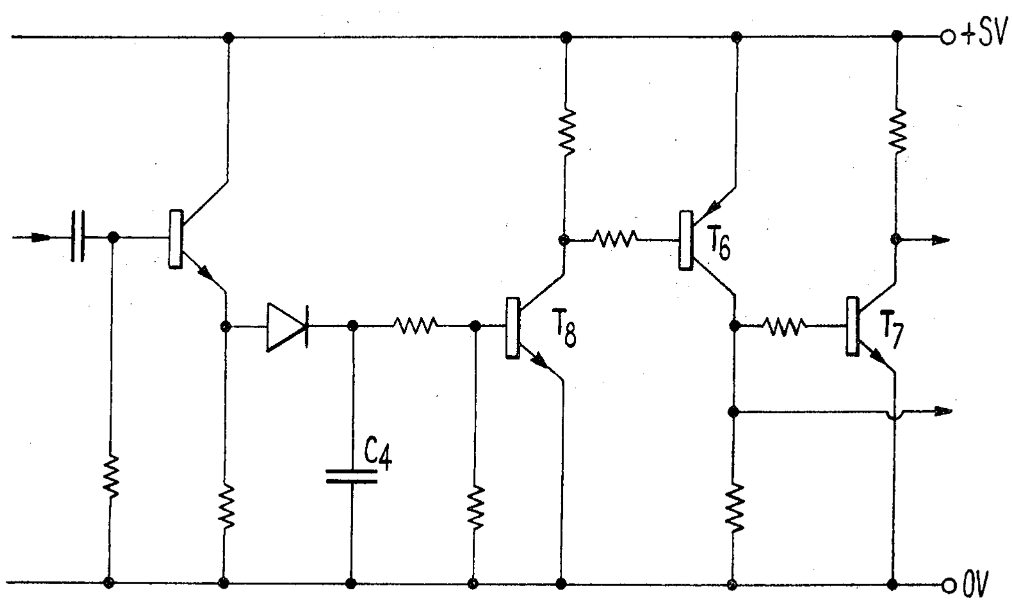

FIG. 8

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PATENTED MAR 28 1972 3,652,798

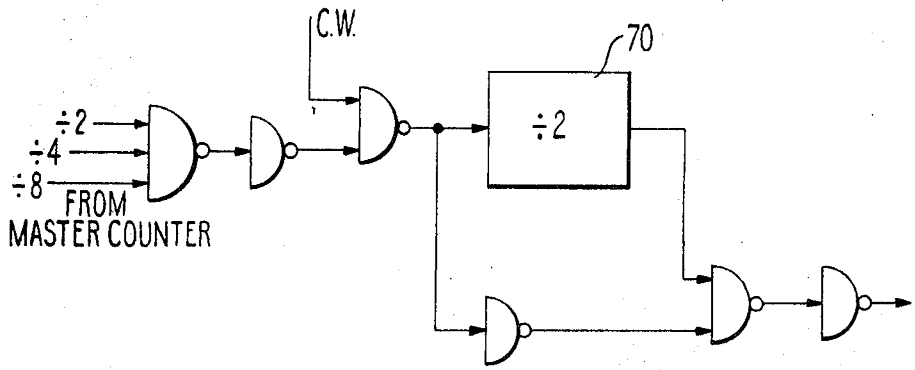

FIG.7

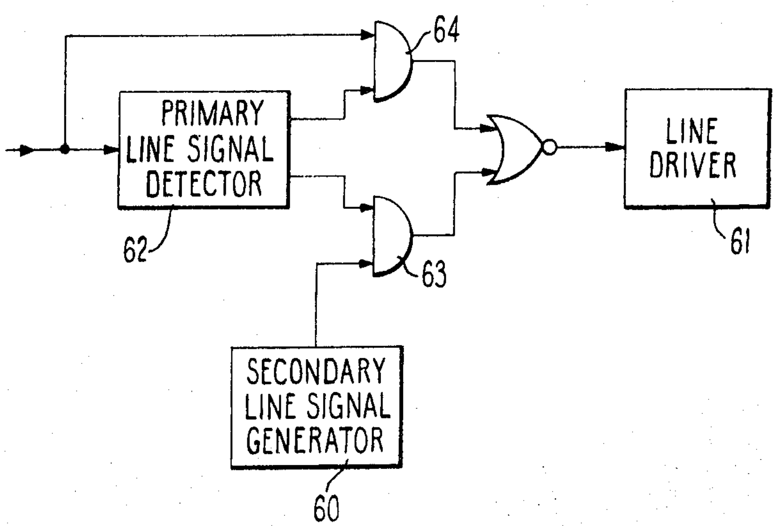

FIG.6

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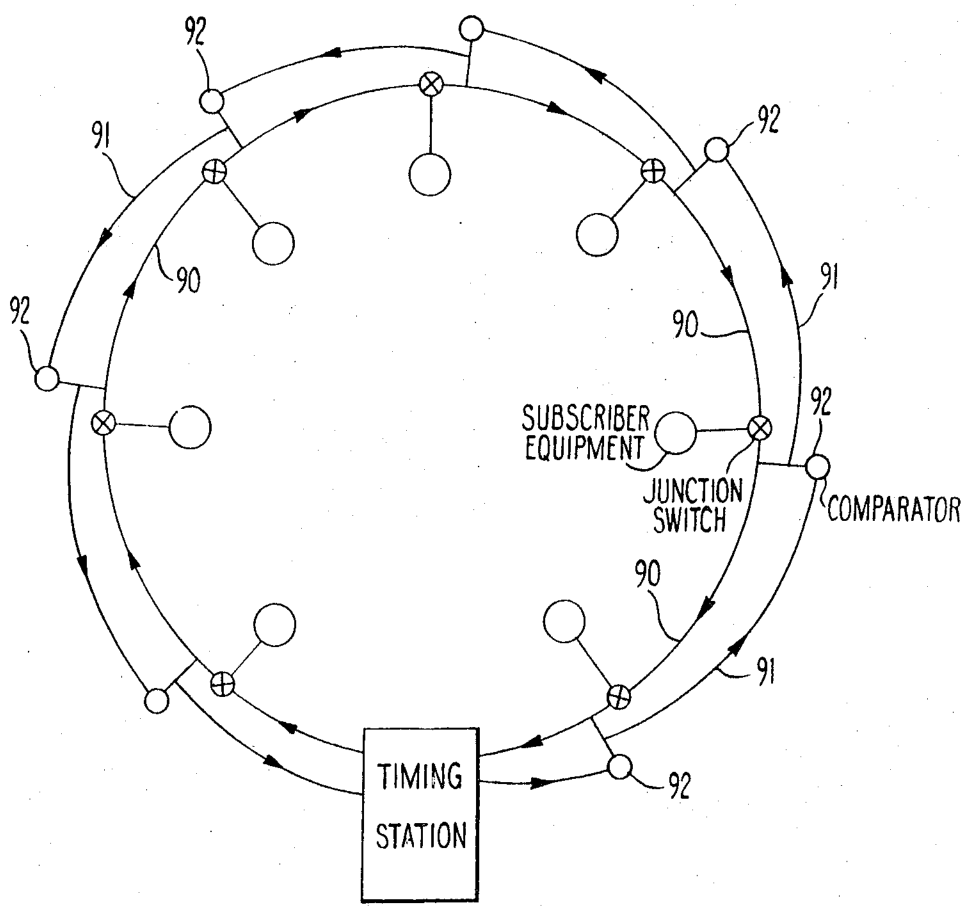

FIG. 9

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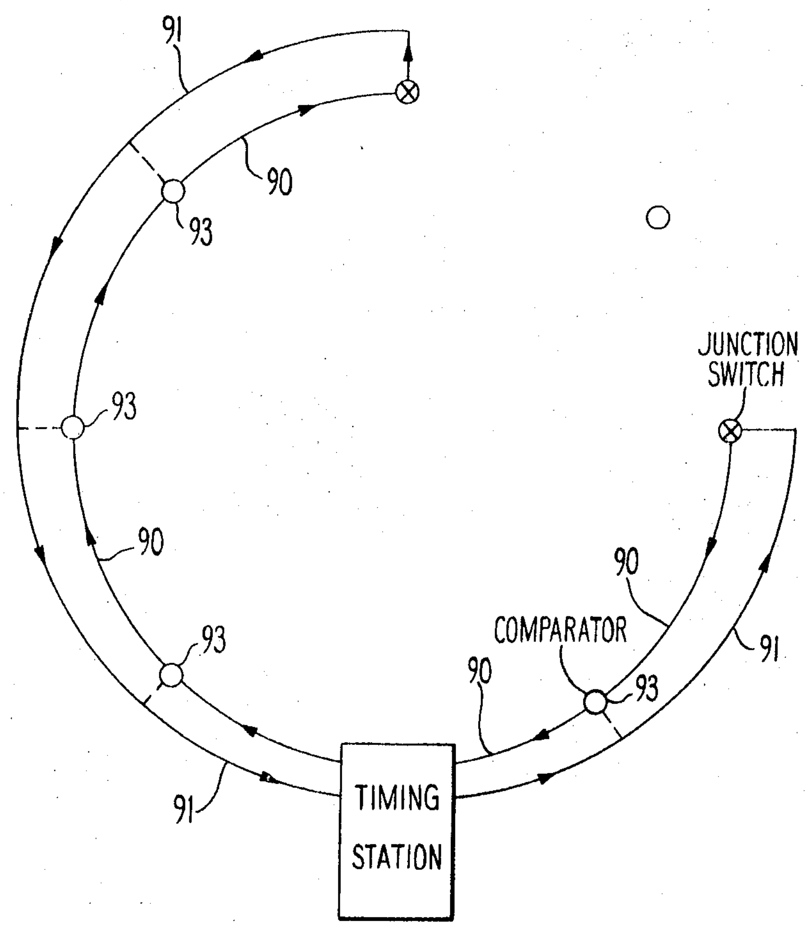

FIG. 10

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PATENTED MAR 28 1972 3,652,798

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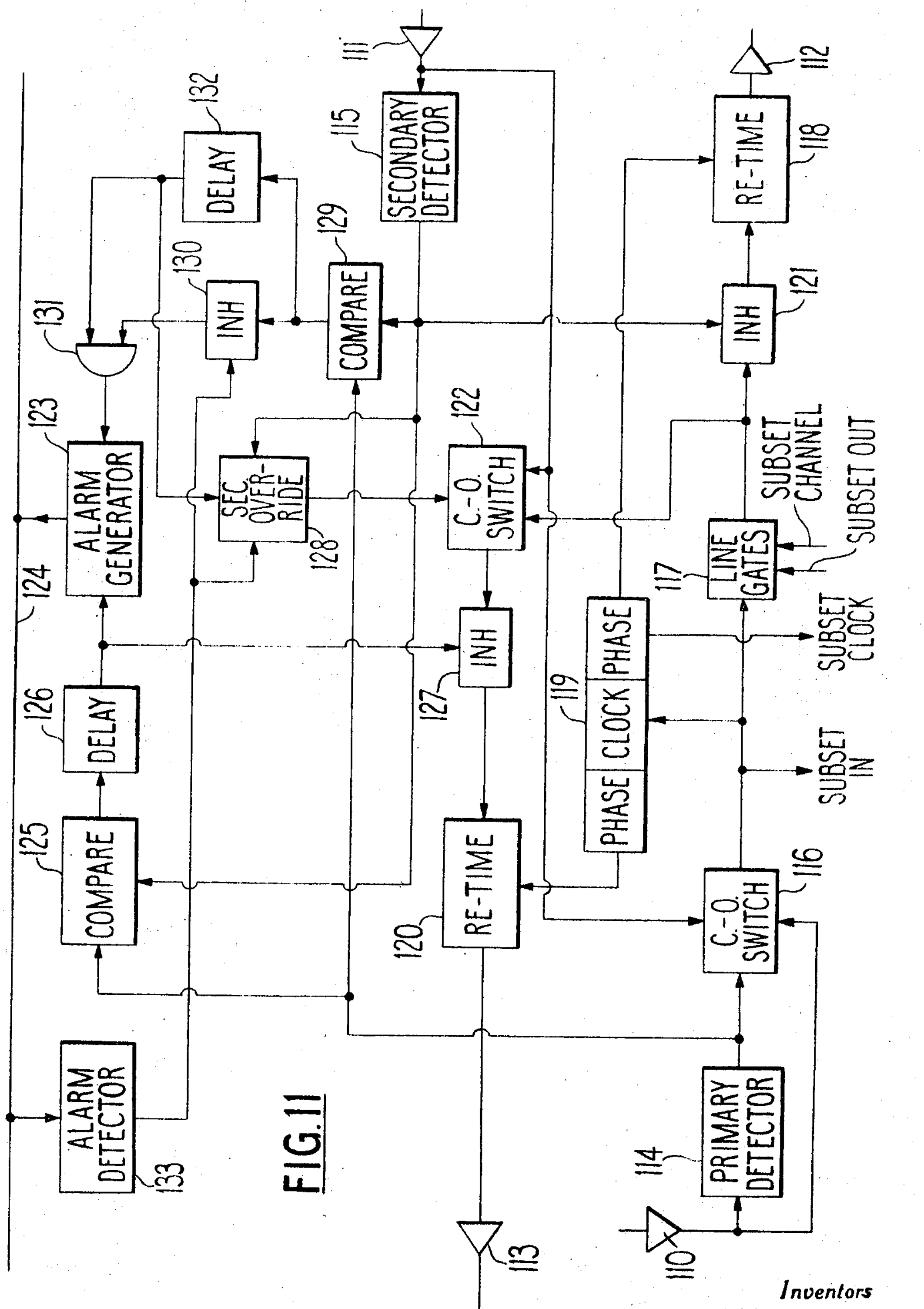

FIG.11

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TELECOMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

This invention related to telecommunication systems, such as PCM (pulse code modulation) telephone networks, in which a group of subscribers have access to a common "ring main" loop line arranged for the continuous unidirectional circulation of time division multiplexed PCM signals.

Subscribers on the loop communicate with one another by seizing a free time slot in the loop by means of a line connecting means which connects the subscriber to the loop at the appropriate times. Signals from a first subscriber destined for a second subscriber are transmitted around the loop as far as the second subscriber and there terminated, while signals from the second subscriber for the first subscriber are transmitted around the remainder of the loop as far as the first subscriber and there terminated. If a subscriber is engaged in a call all other signals are merely regenerated and retimed and passed on to the next subscriber. The system makes use of subscriber equipment which incorporate individual pulse modulating and demodulating means, i.e., each subset includes a PCM coder and decoder. The advent of integrated solid state circuits enables such coder/decoders to be built into conventional sized telephone sets alongside other digital equipment, such as synchronizing, dialing and other circuits which can also be constructed in integrated circuits. This type of telecommunication system is fully described in the U.S. copending application of D.L. Thomas, Ser. No. 763,874, filed Sept. 30, 1968 having the same assignee as the present patent application.

A disadvantage of the system as outlined above is that if there is a break of fault in the system, i.e., a break in the ring main loop, then, since all signals have to pass round the loop, the system as a whole fails.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a telecommunication system of the type described above which overcomes the above-mentioned disadvantage of such systems.

Another object of the present invention is to provide an arrangement for a telecommunication system of the type described above to protect such a system against a failure in the loop thereof.

A feature of this invention is the provision of a telecommunication system comprising a first closed loop unidirectional transmission line for transmitting signals in one direction; a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to the one direction; first means coupled to the first and second lines for providing on one of the first and second lines a plurality of time division multiplexed communication channel signals; and a plurality of subscriber stations coupled to the first and second lines, each of the stations including second means to connect that one of the stations to the one of the first and second lines to establish communication on an unused one of the channel signals with an idle one of the stations, third means for detecting a first fault in the one of the first and second lines, and fourth means coupled to the third means responsive to a detected first fault to interconnect the first and second lines and transferring the channel signals on the one of the first and second lines to the other of the first and second lines, thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass the fault.

According to the present invention there is provided a telecommunication system including a plurality of subscriber stations, a first closed loop unidirectional transmission line to which each subscriber may be connected, means for providing on the looped line a number of time multiplexed communication channels, each subscriber having synchronizing means whereby that subscriber may be connected to any unused channel to make a connection to another subscriber not already engaged in an existing connection, a second unidirectional transmission line parallel to the first line to which each of the subscribers and the channel providing means may be connected, each subscriber station having means for detecting a fault condition in the first line and means for terminating each line and transferring the signals from one line to the other line in the event of a fault being detected, the transferred signals being propagated in opposite directions round the two lines, means for generating an alarm signal indicating a fault condition, and means responsive to such an alarm signal to inhibit the terminating of the two lines in all subscriber stations except those initially detecting a fault condition.

Thus, if a fault occurs in the first loop, which is the one normally in use, at the station immediately preceding the fault the signals are transferred to the second loop and sent all the way back to the station immediately following the fault, where the signals are transferred back to the first loop. In other words, if the first loop is broken, a new loop approximately twice the length of first loop is created which still connects all the subscriber stations except the faulty one. If two or more faults occur, then that section of the system, between two faults, which contains the timing station remains in operation as a shortened double length loop.

The present invention is concerned only with avoiding faults which occur in the loop lines or the subscriber stations. For the purposes of this specification, it will be assumed that the timing station is operating correctly.

BRIEF DESCRIPTION OF THE DRAWING

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of the basic structure of a PCM ring-main telephone system with two looped transmission lines in accordance with the principles of the present invention;

FIG. 2 is a block diagram of the system of FIG. 1 when a fault occurs in a subscriber station;

FIG. 3 is a block diagram of part of a subscriber station in the system of FIGS. 1 and 2;

FIG. 4 is a schematic diagram of the line fault detector used in the subscriber station of FIG. 3;

FIG. 5 is a schematic diagram of the automatic reset logic used in the subscriber station of FIG. 3;

FIG. 6 is a block diagram of additional circuitry used in the timing station of FIGS. 1 and 2;

FIG. 7 is a block diagram of a secondary line signal generator used in the timing station circuitry of FIG. 6;

FIG. 8 is a schematic diagram of a primary line signal detector used in the timing station circuitry of FIG. 6;

FIG. 9 is a block diagram of another embodiment of the basic system of FIG. 1;

FIG. 10 is a block diagram of the system of FIG. 9 when a fault occurs in a subscriber station; and

FIG. 11 is a block diagram of the circuitry of part of a subscriber station in the system of FIGS. 9 and 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the system shown in FIG. 1, the timing station 1 generates a synchronizing signal in one channel of a time division multiplex multichannel frame and empty-channel signals in all the other channels. These signals are transmitted unidirectionally around the closed loop unidirectional transmission line 2, hereinafter referred to as the "primary line." Each of the subscriber stations include subscriber equipment 3–8 and junction switches 3*a*–8a. Equipment 3–8 has access to line 2 and to the TDM channel signals thereon via its associated one of junction switches 3*a*–8*a*. All the primary line signals are fed into each subscriber station. A call from one subscriber to another is effected by the calling station identifying and locking on to an empty channel. The empty channel signal is replaced by a signal identifying the called subscriber. The latter recognizes its own unique signal on a hitherto empty channel and locks onto that channel. The called station modi-

fies the identity signal to indicate that it is ready to proceed with a call — this modified signal travels round the remainder of the primary line loop to the calling station which is then able to put PCM speech signals into the channel. If the called station is already engaged, the unmodified identity signal is allowed to proceed past the called station and when it is received back at the calling station the latter recognizes it as a busy signal.

It will be appreciated, therefore, that, in the absence of any special fault-avoidance arrangements, any fault which breaks the primary line would disable the entire system.

According to the present invention the system includes a secondary line **9** running parallel to the primary line. Signals on the secondary line travel in the opposite direction to those on the primary line. Under normal operating conditions, the secondary line carries a unique standby signal generated at timing station **1**. Each subscriber station junction switch has facilities for distinguishing between the presence and absence of signals on either line. The system also includes facilities for generating alarm signals and each junction switch has means for detecting the presence of alarm signals generated by other junction switches.

The system to be described can deal with the following faults:

a. Both primary and secondary lines open circuit or short circuit;

b. Primary line open circuit or short circuit;

c. Secondary line open circuit or short circuit; and

d. Two or more of the above faults occurring simultaneously.

Consider the operation of the junction switches shown in FIG. **1**. During normal operation each junction switch completes the primary line by virtue of a connection from A to B. The secondary line is completed at each switch by a connection from C to D.

Consider now the fault situation illustrated in FIG. **2**, where a fault occurs in subscriber station **6** such that the system as a whole fails. Junction switch **7***a* detects the absence of signals on the primary line and diverts the output from D, which would have otherwise gone to **6***a*, to terminal A in **7***a*. At the same time it sends an alarm signal out over the primary line to junction switch **8***a*. Junction switch **8***a* detects initially the absence of signal on the primary line and operates to break the two lines and connect A to D as in the case of junction switch **7***a*. However, it is still able to receive the alarm signal from **7***a* and when this is received the A to D connection is broken and the switch reverts to normal operation. This procedure is repeated until the alarm signal reaches junction **5***a*, where it is transferred to the secondary line and so eventually reaches timing station **1** for the second time, having once passed through timing station **1** on the primary line. The timing station then removes from its outgoing secondary line **9** the unique standby signal and connects the outgoing line directly to a bypass connection in the timing station.

Timing station **1**, therefore, incorporates three extra circuits for the purposes of the present invention, a standby signal generator, a primary line signal detector and a bypass switch.

Thus, after only a brief pause, all the subscriber stations except station **6** are again connected by a new unbroken closed loop line running through junction switches **3***a*, **4***a* and **5***a* on the primary line, returning through **4***a*, **3***a*, timing station **1**, **8***a* and **7***a* on the secondary line and, thus, finally back to timing station **1** through **7***a* on the primary line.

Should a fault occur in one of the lines between two subscriber stations the same procedure occurs with respect to the station which detects the fault. Thus, if the primary line is broken or short circuited between stations **5** and **6**, the transfer and alarm procedure is initiated by junction switch **6***a*. At the same time, secondary line **9** is interrupted by the transfer switching operation in junction switch **6***a* and junction switch **5***a* detects the loss of standby signal in secondary line **9** and initiates a transfer procedure as before. Again the system is restored to full operation — this time without the loss of a subscriber station.

If the fault between stations **5** and **6** was in the secondary line similar procedures would be followed, except that in this case junction switch **5***a* would be the first to respond.

If two or more faults occur simultaneously, the subscribers on either side of timing station **1**, between timing station **1** and the nearest fault, will be provided with restricted service, but the subscribers between the faults will lose their service.

The main parts of a subscriber station junction switch relating to the present invention are illustrated in FIG. **3**. The points A, B, C, D correspond to A, B, C, D in FIGS. **1** and **2**.

In normal operation, the primary line input is connected to the primary line output via the primary line receiver **30**, gates **31**, **32**, the speech and dialling portion of the subset, gates **33**, **34** and **35**, and the primary line driver **36**. Similarly, the secondary line is completed through receiver **37**, gates **38**, **39**, **40**, **41**, **42** and driver **43**.

When a faulty condition occurs so that there is a loss of signal on the primary line input, this is detected by primary line detector **44**. As a result of this gate **31** is disabled, gate **41** is disabled and gate **45** is enabled. The junction switch is, thus, isolated from the primary and secondary lines on the fault side of the switch and the signals appearing at D on the secondary line are transferred to A on the primary line via gate **45**.

Should the fault be on the secondary line, secondary line detector **46** operates in exactly the same manner the signals at point B are transferred via gate **47** to point A.

The function of line detectors **44** and **46** is to detect the absence of a line signal. This is achieved in the circuit shown in FIG. **4**. A return-to-zero, 50 percent duty cycle, line signal is used. The line signal, after amplification and inversion in transistor T_1 is passed on through diode D_1 to be integrated and stored on capacitor C_2. Provided that the potential across capacitor C_2 is greater than V_{BE} (base to emitter voltage) of transistor T_3, transistors T_3 and T_4 will conduct with their collectors approximately at 0 and + 5 volts, respectively. These are the potentials required for the junction switch to pass the line signal through. When line signal disappears, capacitor C_2 loses its charge through resistor R_2 and base-to-emitter resistance R_{BE} of transistor T_3 (neglecting other factors) until the potential across capacitor C_2 drops below the V_{BE} junction potential of transistor T_3. Transistors T_3 and T_4 will then be nonconductive with the collectors approximately at + 5 volts and 0 volts, respectively. The potentials from the line detectors are now reversed causing the junction switch to divert the line signal from one closed loop line onto the other closed loop line in response to a fault.

Resistor R_1, capacitor C_1, transistor T_2 and diode D_2 form a circuit that prevents the system from locking itself into the shortest loop at the instant of switching on the power supply, i.e., at the instant of switching the power supply on capacitor C_1 presents a short circuit to base collector junction of transistor T_2, making transistor T_2 conductive, thus, causing capacitor C_2 to be charged through D_2. The potential across capacitor C_1 rises with a time constant C_1 R_1 towards the supply voltage. When the potential across resistor R_1 falls below the potential of the base-emitter junction of transistor T_2, transistor T_2 stops conducting, and the charge on capacitor C_2 leaks away in a normal way through R_2 and the base-emitter resistance of transistor T_3. The time constant C_2 R_2 T_3 (R_{BE}) is sufficiently long ($\approx$100 μsec.) to keep the junction switches conductive until both primary and secondary lines complete the longest new closed loop ring.

Transistor T_5 is used to monitor the presence of a line signal on the ring. Normally, transistor T_5 is non-conductive with the monitor (lamp L) off. When the line signal disappears, transistor T_5 conducts, bringing the monitor on, thus, indicating a fault.

When a fault occurs each junction switch in turn would detect the absence of signal. The system would, therefore, tend to lock itself onto the shortest loop around the timing station. To prevent this happening an automatic reset (**48**, **49** FIG. **3**) is included. This comprises a monostable **51** and an output gate **52** (FIG. **5**). The input to the automatic reset is derived from the line detector. When a signal disappears, the outputs

of a line detector change state causing the monostable to produce an output pulse. The pulse width is determined by the time constant of capacitor C_3 and resistor R_3 in FIG. 5, e.g. approximately 100μsec. For the duration of this pulse, a simulated line signal (C.W.) will be sent to the proceeding junction switch commanding it to hold the junction switch ready to receive the true line signal. As explained previously, all the junction switches to the left and to the right of the fault will receive the automatic alarm signal, except the two nearest the fault. These two will remain in the new state, i.e., transferring the signal from one line to the other. Thus, due to automatic reset the longest loop round the ring has been established. In the case of multiple faults, the subscribers on each side of timing station **1**, between station **1** and the faults will form a new loop, those between the faults will lose service.

The junction switch shown in FIG. **3** also includes manual reset arrangements to bring the faulty section into the circuit after it has been repaired or replaced. A push button **50** is depressed and substitutes a C.W. signal for the DC supply to gate **35** and, via the connection X — X, to gate **42**. The appearance of this C.W. signal on the primary and secondary lines at the adjacent junction switches is detected by the appropriate line detectors and makes them conducting, ready to receive the line signals. When the push button is released the line signals keep the line detectors in the conducting condition, the transfer connections are broken and the line signals are re-routed through the re-connected section.

FIG. **6** shows the additional circuitry required in timing station **1**, said copending application disclosing the remaining equipment of station **1**. The secondary line signal generator **60** is used to generate the unique or standby signal applied to the secondary line driver circuit **61**. When a fault occurs this signal is replaced at some point in the system by the re-routed primary line signals. The primary line signal detector **62** detects the loss of the standby signal and disconnects the signal generator **60** from the driver circuit **61** by closing gate **63**.

At the same time it completes the loop by energizing gate **64** creating a direct link between the secondary line input and output.

The secondary line signal generator is shown in more detail in FIG. 7. Basically a train of pulses (i.e., the empty channel pulses) from the timing station master counter is gated with the C.W. signal and divided by two in the divider circuit **70**. The divider output is gated with the input and the resultant pulse train is applied to the secondary line driver circuit. This signal has a pulse repetition rate half that of the primary line signals.

The primary line signal detector **62** is shown in detail in FIG. **8**. The function of the detector is to distinguish between the primary and secondary line signals on the secondary line input to the timing station. Normally, when a secondary signal is being received, the transistors T_6 and T_7 are nonconductive, keeping their collectors at 0 and +5 volts, respectively. Now, if a primary line signal appears on the secondary ring or line, and because its p.r.f. is at least twice the secondary line signal, the charge in C_4 increases sufficiently to bring transistor T_8 into conduction, causing transistors T_6 and T_7 to conduct, thus, changing their collector potential to + 5.0 and 0 volts respectively. This change of state in transistors T_6 and T_7 collectors activates a changeover switch in timing station **1**. Thus, the transmission of the secondary line signal ceases, and the primary signal will be transmitted instead. Now the primary signal leaves timing station **1** on the secondary line and returns to the timing station on the primary line, thus, completing the second half of the new loop.

FIG. **9** is a block diagram of another embodiment of the system of this invention. In this embodiment, the output to primary line **90** at each station is also sent back along secondary line **91** to the previous station. Each station has a comparator **92** by which it compares its own output with that of the next station along primary line **90**. The degree of comparison may only be sufficient to establish that both stations are producing a digital output, or it may be precise enough to establish a high degree of correlation between the two signals.

If a signal is present at the output to a station on the primary line and no signal is received back on the secondary line, then a fault condition exists at the next station, or on the line between the two. This causes the mode of operation to change as shown in FIG. **10**. At the station where the fault is detected a special alarm signal is generated, preferably out-of band and carried on a separate wire (not shown), and this signal is sent back through all the stations on the line including the timing station. The station which generates the fault signal continues to send back its own output and stops transmitting it in the forward direction, but all other stations on receipt of the alarm signal no longer send back their own output, but instead retransmit the signal coming in on the secondary line. Thus, the secondary line is made continuous from the station which first detects a fault back to the timing station and beyond. After passing through the timing station, the secondary line is still carrying a signal identical to the output from the station which detected the fault, and, because of the fault, there is no signal on the primary line.

To find the best point for feeding the secondary line back onto the primary, it is necessary to introduce another set of comparators **93**. The first set compared the output from a station on the primary with the input on the secondary. The second set must compare the input to the station on the primary with the output on the secondary. This second set should be able to set and reset automatically depending on the inputs. If no signal is coming in on the primary line, then the signal on the secondary is injected, however, if later on a signal does appear on the primary, then it will have priority and will be relayed through the station in the normal way.

When a break occurs there will be no signal on the primary beyond the break. Each of the second group of comparators **93** on this section of the ring will register the absence of the primary and cause the signal on the secondary to be fed onto the primary. Since the comparators are reversible, they will all switch back again except the one closest to where the break occurred, thus, providing the closed loop of FIG. **10**. If, after a few frames delay, a comparator of the second set is still causing the secondary signal to be fed onto the primary, then that station will also initiate the alarm. It will then continue feeding the secondary ring back onto the primary, but will stop transmitting the secondary signal to the next station. In this way the operating alarm circuits are duplicated so that even with the failure of one alarm, the change-over in operating conditions can still be carried out. Once an alarm has been set and the signal is being sent back along the other line, then inhibiting the further forward transmission into the damaged section ensures that intermittent faults are treated as permanent breaks. A station generating the alarm signal can only be reset manually.

The first set of comparators cause the system to switch between the two modes of operation: either sending back their own output on the secondary line or, in the presence of the alarm, relaying the signal coming in on the secondary. If the alarm is removed, or if the signal on the secondary line disappears due to a second fault developing, then the comparators revert to sending back their own output and continue to do so for a number of frames. This should restore the secondary input to all but the one closest to the fault. Either the alarm signal is still present, in which case all stations, except the one registering the new fault, switch back to acting as relays on the secondary or, if the original alarm signal has been removed by the fault, they will not switch back until the station registering the new fault has begun to generate and transmit the fault alarm signal. A station can only initiate the alarm signal after having transmitted its own output for a number of frames, and not if the secondary line signal disappears while it is acting as a relay on the secondary. In this way the second fault is located and the loop reconnected to include the maximum possible number of subscribers. Only the section between the two faults is excluded from service. The same process operates for a greater number of faults.

If the second fault occurs on the timing station primary output, then for half of the system of FIG. **10** the primary line

signal disappears. This is corrected as before: if no signal is coming in on the primary line then the signal on the secondary is injected. However, if later on a signal does appear on the primary then it will have priority and will be relayed through the subset in the normal way.

The constructional details of a subscriber station for the system shown in FIGS. 9 and 10 will now be described with reference to FIG. 11. The primary and secondary line inputs are terminated by their respective line receivers **110**, **111**. The outgoing signals are fed to the lines by the primary and secondary line drivers **112**, **113**. The primary and secondary line detectors **114**, **115** detect the presence or absence of line signals on the incoming lines.

If the primary signals are present they are allowed through the switch **116** to the subset line gates **117** and on to the retiming circuit **118** and primary line driver **112**. The signals passed to the line gates **117** are used to drive the local clock circuit **119** which includes phase selectors which control the retiming circuits **118**, **120**. The outputs of the two detectors **114** and **115** are the signals which are used for comparison purposes as outlined above. In this context "comparison" merely means "are both signals present or is one absent?"

It must be remembered that when a fault occurs, in either the primary or the secondary, two stations will detect the fault condition, one on either side of the fault. In both cases an alarm signal is generated by the alarm circuit **123** and sent out over the alarm wire **124**. Three sets of circumstances will now be considered:

a. Failure in the primary line input;
b. Failure in the secondary line input; and
c. Receipt of an alarm signal on the alarm wire.

a. A fault occurs in the primary line between the station under consideration and the preceding station, i.e., the absence of a primary signal is detected by the detector **114**. In terms of FIG. **11**, the station concerned is the one to the right of the fault and this station is required to transfer the incoming secondary signal to the primary line where it forms the input to the subset and is then fed to the primary line driver. Therefore, detector **114** operates change-over switch **116** and the secondary signal replaces the primary signal at this point. At the same time comparator **125** generates an output if the secondary signal is present and the primary signal is absent. This output, after being delayed for a short time, typically two or three frames, by delay **126**, operates the alarm generator **123** which puts out an alarm signal to the rest of the system over the alarm wire **124**. The delayed output also operates an inhibit gate **127** which cuts off the secondary line output. Thus, the incoming secondary signals are re-routed onto the outgoing primary line.

b. A fault occurs causing the absence of the secondary line signals. This may be due to a fault in the secondary line from the succeeding station to the right, or a fault in the primary line leading to the station on the right. (It has been explained in the preceding example how the secondary signals may be cut off by the operation of gate **127**.)

The secondary line detector **115** operates the inhibiting gate **121** and cuts off the primary output. No change-over of signals is required at changeover switch **122** because under normal conditions it is already passing the primary signals back along the secondary line. Comparator **129** delivers an output when the secondary is absent and the primary is present, and this operates the alarm circuit via the inhibit gate **130** and the OR gate **131**. Since the alarm will be picked up immediately by the stations own alarm detector **133** which, for reasons to be explained later, is the control for the inhibit gate **130**, a bypass for this gate is provided via the delay circuit **132**. The alarm detector also controls gate **128** the function of which is explained below.

c. When no fault is detected by the station under consideration, but a fault is detected by another station, an alarm signal is detected by the alarm detector **133**. The station is required to remove the primary signal which up till now has been returned on the secondary line to the preceding station and to replace it with the secondary line input.

The receipt of an alarm signal coupled with the presence of the secondary signal, as detected by detector **115**, allows the output of delay **132** to pass through gate **128** and operate the changeover switch **122**. This replaces the outgoing primary signals on the secondary line with the incoming secondary signals.

Suppose now that a second fault occurs which is detected at the station under consideration. The second fault can be either a failure of the primary input, or a failure of the secondary input. If the secondary input disappears, the relevant output of detector **115** overrides the existing alarm signal at gate **128** and removes the control from changeover switch **128**. This restores the primary signal to the outgoing secondary line and the operating procedures are otherwise as described in (b) above. If the primary signal fails, the output of detector **114** inhibits the input to delay **132** by operating comparator **129**. This also removes the control from gate **128** and the remaining procedures are as described in (a) above.

It will be noted that once a station has responded to an alarm generated elsewhere it will not be affected by further simultaneous alarms from other stations. Any alarm will be maintained so long as a fault condition remains.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A telecommunication system comprising:
a first closed loop unidirectional transmission line for transmitting signals in one direction;
a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to said one direction;
first means coupled to said first and second lines for providing on one of said first and second lines a plurality of time division multiplexed communication channel signals; and
a plurality of subscriber stations coupled to said first and second lines, each of said stations including
second means to connect that one of said stations to said one of said first and second lines to establish communication on an unused one of said channel signals with an idle one of said stations,
third means for detecting a first fault in said one of said first and second lines, and
fourth means coupled to said third means responsive to a detected first fault to interconnect said first and second lines and transfer said channel signals on said one of said first and second lines to the other of said first and second lines, said first and second lines thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass said first fault;
each of said stations further including
fifth means coupled to said third means for generating a first alarm signal upon detection of said first fault for transmission on said one of said first and second lines; and
sixth means responsive to said first alarm signal to inhibit said interconnection of said first and second lines in all of said stations except those of said stations initially detecting said first fault.

2. A system according to claim 1, wherein
each of said stations further include
seventh means for detecting a second fault in said other of said first and second lines; and
eighth means coupled to said seventh means responsive to a detected second fault to interconnect said first and second lines and transfer said channel signals on said other of said first and second lines to said one of said first and second lines, said first and second lines

thereby cooperating to provide a second new closed loop unidirectional transmission line to bypass said second fault.

3. A system according to claim 2, wherein
each of said stations further include
ninth means coupled to said seventh means for generating a second alarm signal upon detection of said second fault for transmission on said other of said first and second lines, and
tenth means responsive to said second alarm signal to inhibit said interconnection of said first and second lines in all of said stations except those of said stations initially detecting said second fault.

4. A system according to claim 3, wherein
each of said third means and seventh means includes
eleventh means for generating two different signals having a predetermined relationship in the absence of any fault,
twelfth means coupled to the associated one of said first and second lines for integrating and storing signals received from said associated one of said first and second lines,
a first source of reference signal having a given amplitude value,
thirteenth means coupled to said first source and said 12th means for comparing the amplitude value of said stored signal with said given value of said reference signal, and
fourteenth means coupled to said 13th means responsive to a predetermined change between said value of said stored signal and said given value of said reference signal to reverse said predetermined relationship of said two different signals.

5. A system according to claim 4, wherein
said first means further includes
fifteenth means coupled to said other of said first and second lines to transmit a unique signal thereover; and
each of said stations further includes
a second source of signal simulating said unique signal,
a monostable device coupled to said eleventh means responsive to one of said two different signals having a predetermined condition to produce an output pulse of predetermined width, and
gated means coupled to said second source, said monostable device and said associated one of said first and second lines responsive to said output pulse to couple said simulated unique signal to said associated one of said first and second lines for a duration equal to said predetermined width.

6. A system according to claim 5, wherein
said first means further includes
sixteenth means coupled to said other of said first and second lines for detecting thereon signals normally appearing on said one of said first and second lines and producing a control signal under this condition; and
seventeenth means coupled to said 16th means and said 15th means responsive to said control signal to inhibit the transmission of said unique signal and to connect said other of said first and second lines coming into said first means directly to said other of said first and second line leaving said first means as long as said control signal is present.

7. A telecommunication system comprising:
a first closed loop unidirectional transmission line for transmitting signals in one direction;
a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to said one direction;
first means coupled to said first and second lines for providing on one of said first and second lines a plurality of time division multiplexed communication channel signals; and
a plurality of subscriber stations coupled to said first and second lines, each of said stations including
second means to connect that one of said stations to said one of said first and second lines to establish communication on an unused one of said channel signals with an idle one of said stations,
third means for detecting a first fault in said one of said first and second lines, and
fourth means coupled to said third means responsive to a detected first fault to interconnect said first and second lines and transfer said channel signals to said one of said first and second lines to the other of said first and second lines, said first and second lines thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass said first fault;
each of said stations transmitting over said other of said first and second lines the signals also transmitted over said one of said first and second lines; and
each of said stations further including
fifth means coupled to said first and second lines for comparing the signals received over said one of said first and second lines from the next preceding one of said stations with the signals received over said other of said first and second lines from the next succeeding one of said stations,
sixth means coupled to said fifth means for detecting a first predetermined degree of discrepancy between the compared signals,
seventh means coupled to said sixth means for generating an alarm signal in response to the detection of said first discrepancy,
eighth means responsive to an alarm signal generated by another one of said stations to inhibit the transmission of signals over said other of said first and second lines and to connect the incoming said other of said first and second lines to the outgoing said other of said first and second lines,
ninth means coupled to said sixth means responsive to the detection of said first discrepancy to inhibit the transmission of signals over said one of said first and second lines,
tenth means coupled to said first and second lines for comparing the signals received over said one of said first and second lines with the signals received over said other of said first and second lines,
eleventh means coupled to said 10th means for detecting a second different predetermined degree of discrepancy between the signals compared in said 10th means; and
twelfth means coupled to said 11th means responsive to the detection of said second discrepancy to transfer signals received over said other of said first and second lines to said one of said first and second lines, said 12th means being inhibited when said second discrepancy is no longer detected.

8. A system according to claim 7, wherein
each of said stations further includes
thirteenth means coupled to said 11th means responsive to the detection of said second discrepancy for generating an alarm signal.

9. A system according to claim 8, wherein
each of said thirteenth means includes
fourteenth means coupled to said eleventh means for inhibiting the generation of said alarm signal for a given period of time after the detection of said second discrepancy.

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